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Tasks 6
FINAL REPORT

Project

ASHRAE 1286-TRP
Evaluation of Building Energy Performance Rating Protocols

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Prepared for

Project Monitoring Subcommittee
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Executive Summary

Building energy performance rating methods provide a way to compare the energy consumption of one building with other similar buildings. Building owners may use rating methods to determine if investment in energy efficiency retrofits is justified. Developers are using building energy performance ratings to showcase high performance buildings. Tenants are attracted to buildings with high energy performance ratings as a way to minimize facility operating costs. By highlighting efficient buildings, energy performance rating methods stimulate the design and construction of buildings using less energy. Energy efficiency contributes to overall building sustainability, which also includes land use, water use, and material use.

Many different rating methods were uncovered by a formal literature search and an informal Internet search including 47 protocols for commercial buildings and 31 that applied to residences. Most of the residential protocols were based on point systems which have achieved a high degree of market penetration in the home building industry. Rating methods that apply to commercial buildings were the main focus of this research and five were selected for in-depth investigation based on a range of criteria including the use of ASHRAE documents, the approach used, the range of building types, perceived number of users, and amount of technical documentation available. Eight ASHRAE standards, two guidelines and the ASHRAE Handbook of Fundamentals were employed by various rating methods, mostly those using a point system. The five methods selected for in-depth evaluation were LEED-NC/LEED-EB, ENERGY STAR Label for Buildings, BREEAM, ARCH/CALARCH, and ENERGYguide. These rating methods were each selected due to their widespread adoption, business focus, or use of simple energy use intensity calculations.

In order to test and understand the ratings from these protocols, data from actual buildings was gathered. The detailed questions that are part of the LEED and BREEAM rating methods made contacting building operator or facility managers necessary. Public information from buildings that have been rated under the ENERGY STAR Label for Building program and the LEED program included contact information. A subset of people were contacted and asked to complete a questionnaire about their building. Data on 29 buildings including 15 office buildings, nine schools, four hospitals, and a hotel were gathered and used for testing the rating protocols. In addition, a supplementary database of buildings was developed based on a survey of buildings conducted by the Northwest Energy Efficiency Alliance. Of the 1157 commercial premises in the NWEEA survey, 167 were selected based on building type and availability of actual utility data.

By their very nature, consumption-based protocols such as ENERGY STAR, ENERGYguide, Arch and Cal-Arch, do not integrate well into new building design since they require a year of actual energy consumption. For existing buildings, consumption-based protocols provide direct feedback on energy consumption but do not provide guidance on how to improve the building to obtain a specific rating. This is probably the most significant shortcoming of the consumption-based protocols. Once poor performance is found for a building, the energy professional or designer must try to obtain additional knowledge about the causes of the poor performance in order to identify effective changes and achieve a specific higher score. This means that even if an owner is willing to invest money to alter their building to become an ENERGY STAR labeled building, there are no guarantees of actually achieving that goal.

Design-oriented protocols, such as LEED-NC and BREEAM for design, often use points to reward the inclusion of specific design features. For energy performance, these protocols reward points based on a method such as building energy simulation. Simulation is a good way to compare options but often fails to provide a good prediction of actual energy consumption. This means that design-oriented systems that estimate energy use at design time may result in buildings that use significantly different amounts of energy. Factors such as construction changes, poor commissioning, actual operating schedules, and poor modeling assumptions, can increase actual energy use well beyond the original estimate. On the other hand, if the achievement of a rating is the overall goal, these protocols provide a specific methodology to achieve that goal with minimal risk since actual energy does not impact the rating. Design-oriented protocols cannot apply to existing buildings unless focused on major additions to a building.

Neither design-oriented nor consumption-based protocols provide a guarantee of actually achieving a specific energy performance. Thus, the final link to truly improved energy performance is still missing for all these methods.

When testing the rating methods with the actual building data, see Table ES-1, only four of the 29 buildings were not rated in the top half by one of the five rating methods and only four buildings were rated in the top half by all the five rating methods. Twelve of the buildings were rated in the top half of either all of the rating methods or all but one of the rating methods. Eight of the building where rated in the top half of none or just one rating method. The overall conclusion is that while some exceptionally good buildings are consistently rated well across different rating methods, most buildings could be considered "good" by some rating methods and not others.

Table ES-1 – Buildings in Top Half

Building	*Number of Applicable Rating Methods*	*Number of Methods Placing Building in Top Half*	*Quantity of Methods Placing Building in Top Half*
S-003	5	5	All
L-021	5	5	
O-044	6	6	
O-055	6	6	
O-018	6	5	All But One
H-035	5	4	
S-037	5	4	
S-053	5	4	
S-054	5	4	
H-070	5	4	
S-071	5	4	
H-072	5	4	
O-013	6	4	Some
O-023	6	2	
O-027	6	2	
O-028	6	2	
H-054	5	3	
O-059	6	2	
S-069	5	2	
O-096	6	2	
S-098	5	2	
O-022	6	1	Only One
O-026	6	1	
S-041	5	1	
O-050	6	1	
O-016	6	0	None
S-067	5	0	
O-076	6	0	
O-089	6	0	

The five protocols examined each have their own strengths and weaknesses. A deep examination of the protocols has revealed no single clear winner as the best approach overall. The consumption-based protocols such as ENERGYguide, ENERGY STAR, Arch and Cal-Arch, are available for use at no charge and attract many people based on that. Adding a certification process, such as ENERGY STAR has done, seems to add credibility and spread recognition of the protocol.

The five rating methods that were investigated and tested as part of this project provided a good cross section of different approaches. It is clear that the need for robust and easy-to-use rating methods for buildings will only increase as escalating energy prices brings an increasing awareness to energy conservation. The recommendations based on the research are:

1. EPA should update the references in “Professional Engineer's Guide to the ENERGY STAR ® Label for Buildings” (EPA 2003) to the latest version of Standards 55, 62.1, and 62.2.
2. Appoint a high level liaison between ASHRAE and EPA to see how Standards 52.1, 55, 62.1, and 62.2 could be improved to enhance their usefulness to ENERGY STAR and find out if any other ASHRAE documents could be used or adapted to be used within the ENERGY STAR program.
3. Agree to a Memorandum of Understanding between ASHRAE and EPA establishing and maintaining a mutually beneficial relationship related to ENERGY STAR and ASHRAE standards, research, training, and communications.
4. Appoint a liaison between ASHRAE and USGBC to help enhance Standards 52.2, 55, 62.1, and 90.1 to better meet the needs of USGBC for their LEED-NC for new construction and LEED-EB for existing buildings.
5. In Standard 90.1, create a method of rating energy performance from design to operation which uses the same scale and report operation results back to the original design team.
6. Increase the level of funding and maintain a high level of funding to provide research in support of energy performance rating protocols.
7. Provide ASHRAE training for LEED-NC and LEED-EB compliance focusing on applying the referenced ASHRAE standards.
8. An article concerning ENERGY STAR and the ASHRAE standards it references should appear in a future ASHRAE Journal.
9. Develop and provide a training course on ENERGY STAR and the ASHRAE standards it references.
10. Develop and provide a training course about energy conservation measures for new and existing buildings and how engineers can assess the energy impact of changes.

1 Introduction

Everyday we use ratings to help us make purchasing decisions. For example, we would not purchase a car without understanding how many miles it can go on a gallon of gas and a computer printer would not be considered without understanding the number of pages per minute it can print. Most expensive items have been rated by some measure to allow us to choose the item and understand its level of function. We also use ratings to inform us on how we are doing compared to others. Children receive grades and test scores on each subject in school to understand how they are doing. Adults are concerned with their credit score and cholesterol level as measures of borrowing power and health. These scores or ratings help make the complexity of comparing items within a category simpler to understand. No rating or scoring system is perfect but they provide an overall indicator that may be used to start making decisions or perhaps to begin to focus on the details of a few choices.

The focus of the research reported in this document is building energy performance rating methods. These methods may be used for existing buildings, new construction or both to determine how the building's amount of energy use compare to a group of similar buildings. Again, rating methods for buildings are used to help make purchasing decisions related to those buildings. For existing buildings, a rating method may spur the investment in an energy conservation improvement to the building or, at least, examining the building closer using an energy audit to understand how to reduce energy use in the building. For new construction, building energy performance rating methods can help guide the design process by providing an energy consumption goal or simply by prompting examination of energy use during the design process.

Rating methods become even more useful when only one method is commonly used. Under a single common rating system, discussion of the measure becomes even easier since everyone shares a common understanding of the overall meaning of the rating. In addition, a product that is sold that has not been rated under a single common rating system is unlikely to be purchased, which encourages the widespread use of the rating system. This empowers consumers and business decision makers with a common basis of comparison for all items in a product category.

Many different building energy performance rating methods are available so the advantage having of a single common rating method for consumers and business decision makers does not exist for building energy performance. Someone trying to decide which building to rent for his or her business would not expect to have a common building energy performance rating available for each choice. Instead, a building energy performance rating method could be chosen and rating calculated for each building if sufficient information was available. More likely the utility bills of previous tenants, if available, may be compared with each other. Decisions based on this could lead to an erroneous conclusion concerning which building would minimize energy use or expenditure.

ASHRAE, the sponsor of this research, helps to establish standards for the building sector covering many different HVAC products and for overall efficient building design and operation. It would be a natural fit for ASHRAE to establish a standard method of rating the energy performance of buildings. This research project may be considered one preliminary step to such an effort by close examination of some existing building energy performance methods.

Even if an ASHRAE standard on building energy performance rating never is developed, this report may help those trying to choose between different rating methods. If one or more of the rating methods under consideration were examined, the details can help decide between the different systems. If the rating method was not included in this report, the methodologies described and information gathered may still form the basis of a deeper understanding of rating methods and facilitate choosing a method.

1.1 Value of Benchmarking

The value of energy performance rating, also called benchmarking is summarized as:

Benchmarking can be an excellent tool for characterizing the energy intensity (often measured as annual Btus consumed per square foot) of buildings. It can also be used to track an individual building's performance over time and help monitor or identify opportunities to improve operation and maintenance (O&M) practices. Managers who oversee a number of buildings can use benchmarking results to rank buildings and identify from those that need some immediate attention or those that perform efficiently. While benchmarking cannot give the same level of detail as a good energy audit or full engineering analysis, for a relatively small investment of time and effort, it can provide a good overall picture of energy use for a given facility. It is an easy and worthwhile first step to understanding energy usage and savings potential. (Hinge 2002)

One of the primary reasons for using a building energy performance rating protocol is to allow for the identification of which buildings merit further investigation and investment in energy conserving features. The benefits of commercial building rating are numerous and include:

- An owner of multiple buildings can easily determine which building justifies further investment in energy efficient retrofits.
- Building developers can legitimately claim a project to be "high performance."
- Tenants can be attracted to buildings that demonstrate lower energy usage.
- Program developers for stimulating the construction of high performance buildings need a metric to quantify high performance.
- Energy efficiency contributes to overall building performance that includes sustainability issues including land use, water use, and material use.

1.2 Categories of Rating Protocols

While each building energy rating protocol is different, most fall into one of three broad categories:

- Statistical – Protocols based on a statistical distribution of actual buildings and determining where the building being rated fits within that distribution
- Points – Protocols that provide points to the rated building for best practices used in the building in a long list of criteria
- Prototypical – Protocols that compare the rated building with conceptual buildings based on good practice usually using building energy simulation software.

The implications of each of these categories are described in Table 1. Exceptions for a particular protocol may exist, but the table shows the implications of the generic methodology.

Table 1 – Implications of Categories

Feature	*Statistical*	*Point*	*Prototypical*
Actual Energy Consumption	Yes	No	No
Empirical	Yes	No	No
Input Needed	Small	Large	Varies
Affects Initial Design	No	Yes	Yes
Operation Oriented	Yes	No	No
Based on Building Database	Yes	No	No

All three different methodologies, statistical, point and prototypical, can be vulnerable to providing ratings that do not well reflect the design and operation of the building. Occupant density for example can vary greatly in any building type, even a building type as well defined as an office. Some office buildings have very high occupant densities such as a telemarketing or customer-support facility. Other office buildings may have lower occupant densities such as insurance companies where a large segment of the floor space is taken up by files. These differences make it difficult to create a system that rewards a very efficient high-density building.

The development of a building energy performance rating protocol is not easy. What first appears to be simply an engineering challenge quickly becomes a philosophical debate. Many of the technical decisions made during development have implications on which buildings will be considered above average, average or below average rated buildings. The term energy efficiency is often misapplied, even in the literature, concerning energy ratings of buildings. Buildings that score well may not be technically efficient but simply do not use much energy due to shorter hours of operation or the lack of features. In a recent study (Hinge 2002), modern schools that included swimming pools often scored worse than older schools without such amenities. It raises the question of how to construct a rating procedure that is fair and reflects good energy design and operation.

Another example is high occupant density office buildings that result in high energy use. They could have highly efficient chillers and windows but still score poorly in a rating because of the occupant density. This calls into question the typical use of EUI (energy use intensities) that are normalized by floor area. Instead, a rating system could normalize by other factors such as number of occupants or dollars generated. Others have called for the area used in normalizing to be the area of the building site instead of the floor area to show the impact on land use.

How strong of a signal should be provided by the building energy rating method? Should it be or not be highly sensitive to variations in energy use? Since a building's actual energy consumption varies by the actual weather and other factors, a building's rating could conceivably be different at different points in the building's history. These issues were discussed at two recent forums on building performance metrics (NREL 2001, NREL 2002).

If a statistical approach is used for the rating protocol, should it include all buildings in the original database or only those that have been recently constructed? Should buildings that do not provide the same services (such as air conditioning) be included? If multiple sub-categories of buildings exist such as big box retail, single storefront, chain store, etc. should they be combined in a statistical distribution or each have its own statistical distribution?

As one can see, the questions of categorization, which buildings to include in the database and the simple goal of a rating procedure can spur philosophical issues on the rating protocol. Each of the rating methods examined in the project were viewed in terms of how those questions were answered.

1.3 Scope of Work

The project was conducted over the course of three years and included the following five research oriented tasks and two reporting tasks. Task reports were prepared as part of each task which have been combined for this final report. Progress was monitored and guided by an ASHRAE project monitoring subcommittee.

- Task 1 - Identify and Select Performance Rating Methods for Study. Identify as many current publicly available building energy performance rating protocols being used by practitioners as possible. Select 10 for potential further consideration, placing special emphasis on those that use ASHRAE products, documenting the basis for such selection. Identify 5 of the 10 that are most appropriate to undergo further evaluation in the following tasks.

- Task 2 - Technical Evaluation of Methods. Conduct a detailed technical review of the protocols selected to be able to describe the technical basis, scope of application, apparent strengths, and apparent weaknesses of each method/tool for rating the energy performance of applicable buildings.

Describe the intended audience and to what extent the protocol can be applied. Evaluate the extent to which each is based upon empirical data. Describe the data requirements for each method and to what extent the rating is impacted by input data quality.

- Task 3 - Identification of Buildings on which to Apply the Rating Methods. Identify a minimum of 15 buildings that will be used to apply the selected rating protocols to obtain rating results. Approximately one-third to one-half should be office buildings. Approximately one-third should be K-12 schools. At least four must be buildings that were designed to meet the requirements of ASHRAE Standard 90.1 (1989 or 1999). The rest should be a mix of buildings. Select at least two from the following: a hospital-type facility, a lodging facility, a restaurant of some type, a grocery of some type, and a retail store of some type are desirable. All buildings selected must have data required for use in the rating methods available or easily obtainable. Not all buildings may necessarily be applicable to all rating protocols, depending on scope.
- Task 4 - Application of Selected Rating Methods to Selected Applicable Buildings. Apply the selected rating methods, according to their scope and applicability, to the selected buildings to obtain the output performance ratings. Finalize the evaluation of the technical basis for each method, validity of their scope, strengths, weaknesses, and level of empiricism. Evaluate the user expertise required to effectively use each method and the impact of user skill.
- Task 5 - Development of Recommendations. Develop recommendations on the potential of the methods studied to impact ASHRAE standards, guidelines, future research, training for members and nonmembers, and Society communications. Develop prioritized recommendations on future research related to the results of this project.

Additional technical details on the approach used to perform these tasks are shown in the appropriate sections.

1.4 Evaluation and Application Approach

Each of the five selected rating methods was evaluated in detail with a separate section of this report devoted to each method. Each section also includes testing the rating method using data from the selected buildings. Whereas Section 2 is a broad evaluation of many building energy performance rating protocols, Sections 4, 5, 6, 7, and 8 each focus on providing a deep evaluation specifically focused on the five selected protocols. The goals include:

- Determining the intended group of users such as building owners, operators or designers
- Determining the type of buildings that may be benchmarked including if common variations of those buildings have separate benchmarks.

Data used in producing a rating for each protocol were researched with special emphasis on:

- Understanding the source of the empirical data used
- How representative is the sample used in the data source
- The validity of the dataset selection process, if any is used
- The applicability of the data source for the research project.

The rating algorithm used was researched with emphasis on:

- The statistical methodology used to sort or categorize the building at time of rating
- The approach used to combine fuels and electrical consumption for an overall energy factor
- The approach used to represent the rated building in the distribution of buildings
- The applicability of the algorithm for the research project.

The amount of input data required for each method is also important and is directly related to the usefulness of any future ASHRAE developed building energy performance rating protocols. Several of the selected rating methods require floor area, annual energy consumption and a few other inputs. These numbers are known or can be easily found by building operators.

The primary source of information came from a review of documents related to the building energy performance rating protocols, but it was not the only source of information. To supplement this source of information many questions were directed to technical contacts for each of the selected protocols.

Two sets of buildings were used to analyze the building energy performance rating protocols in the report. The primary set consists of buildings that had been rated by one of the methods with additional data specifically gathered for this project with adequate detail so that they could be used with as many of the rating protocols as possible. A brief questionnaire was sent to the listed point of contact for each of the primary buildings to help provide data not available from the original rating organization. The supplementary set of data is based on an energy oriented commercial building survey and no additional details were gathered for those building other than what was present in the database.

Arch, Cal-Arch, ENERGY STAR for Buildings and ENERGYguide are implemented as Internet web sites, and cases using them were usually run using a standard web browser. The other rating protocols, LEED-EB and BREEAM, were evaluated using spreadsheets replicating the methodology described for the rating protocols. The protocols with a focus on new building design were not analyzed with the primary or secondary buildings. Those protocols, LEED-NC and BREEAM for new building construction, cannot be directly compared with the results of the other protocols so they were not tested.

To better understand how the ratings vary, a sensitivity analysis of the inputs was performed. For each major input, such as the floor area or energy consumption, values 15% higher and 15% lower were evaluated separately. The change in the resulting ratings indicates how each input affects the rating. The sensitivity analysis approach isolates each input variable and allows a determination of how important each input variable is to the rating procedure.

2 Identify and Select Performance Rating Methods

2.1 Objective

In order to broaden the understanding of building energy performance rating protocols, ten different protocols were initially selected for research. Of these, five were selected for immediate research and the remaining five left as alternates in case research could not be adequately performed on the five selected. To capture how these protocols may be used internationally and by different parts of the building community, a good selection of protocols was reviewed. A literature search, a separate web search, and suggestions from the project monitoring subcommittee were used to find these protocols.

2.2 Methodology

Overall, while the formal literature search provided a wealth of references to technical details on different protocols for rating the energy performance of buildings, the Internet search uncovered many more protocols and was the primary method used to research details on each protocol selected.

2.2.1 Formal Literature Search

The research librarians at the Linda Hall Library in Kansas City were used to perform targeted literature searches. The Linda Hall Library specializes in science, engineering and technologies literature. The searches performed included the following phrases:

- Building* and Energy and Benchmark*
- Green Building* and Energy and Rating*
- Green Building* and Energy and Criteria
- Buildings and Energy and Yardstick
- Buildings and Energy and Criteria (in title field only)
- Buildings and Energy and Measure (in title field only)

The asterisks indicate that the ending of the word was allowed to be any value such as “Benchmark” could be “Benchmarks” or “Benchmarking”. Two of the searches were limited to words in the title only because of the large number of unrelated items uncovered during the search. The resulting list of references was reviewed and items that were clearly not relevant were culled from the list.

2.2.2 Internet Search

A thorough search of the Internet was performed using search terms related to the topic area. These searches were performed using Google, which covers over 3 billion web pages. Protocols were not limited to only those used in the United States since the goals of benchmarking are international, and different methodologies in the international community may be of value to the long term goals of the project. The following table indicates the search terms used with Google. The searches were performed in the order shown on the table. The level of success naturally decreased as the search continued and fewer protocols were left to be uncovered. The result of these searches is shown in Table 2.

Table 2 – Search Terms Used on Internet

Search Phrase	Looked Through	Level of Success
building benchmark	50	Good
building energy benchmark	100	Good
building energy rating	150	Good, mostly residential
building energy metric	50	Poor
Building Energy Measure OR Rank OR Gauge OR Grade	50	Poor
Building Energy Criteria OR Classification OR Merit	50	Poor
Building Energy Valuation OR Mark OR Yardstick	50	Poor
Building Energy Target OR Score	50	Poor

2.3 Protocols Found

A selection table of all protocols and all criteria was made that included both commercial and residential protocols. Located were 47 commercial protocols (Table 3) and 31 residential protocols (Table 4). For residential, programs were excluded that simply referenced ENERGY STAR Homes program. Items shown as "(indirect)" were not found on the web search results page but were from a link from a different protocol or were identified by project monitoring subcommittee members.

Table 3 – Initially Identified Commercial Protocols

Name	*Organization*	*URL*	*Found on Search*
Benchmarking Building Energy Performance	ORNL	http://eber.ed.ornl.gov/benchmark/bench.htm	google:building benchmark
ENERGY STAR Label for Buildings	EPA	http://www.energystar.gov/benchmark	google:building benchmark
EEBuildings	EPA	http://www.epa.gov/eebuildings/benchmarking/default.htm	google:building benchmark
Online Benchmarking of Energy Consumption	Hong Kong EMSD	http://www.hkiol.org/energy2/main.html	(indirect)
Free Energy Benchmark	Chevron	https://ssl2.gap.chevrontexaco.com/chevronenergy/benchmark/	(indirect)
Green Globes	Green Globes	http://www2.energyefficiency.org/default.asp	(indirect)
GEM (UK)	Green Globes	http://www2.energyefficiency.org/existing/homeuk.asp	(indirect)
Commercial Building Incentive Program	Natural Resources Canada	http://nrn3.nrcan.gc.ca/cbipscreen/index.html	(indirect)
Benchmarking energy use	The Australian Greenhouse Office	http://www.greenhouse.gov.au/lgmodules/wep/benchmark/index.html	(indirect)
LEED	US Green Building Council	http://www.usgbc.org/	(indirect)
LEED-EB	US Green Building Council	http://www.usgbc.org/	(indirect)
CALARCH	LBL/California Energy Commission	http://poet.lbl.gov/cal-arch/benchmark.html	google:building benchmark
ARCH	LBL	http://poet.lbl.gov/arch/	(indirect)

Table 3 (continued) – Initially Identified Commercial Protocols

Name	*Organization*	*URL*	*Found on Search*
CustomNet	PG&E	http://www.pge.com/003_save_energy/003b_bus/003b2b_custom_net.shtml	(indirect)
Power Smart e.Review	BC Hydro	https://ewh.bchydro.bc.ca/ereview/scripts/main.asp	(indirect)
EMCOR Energy Edge	EMCOR	http://www.emcor-energy-edge.com/	(indirect)
Energy Profiler Online	ABB	http://www.abb.com/global/abbzh/abbzh251.nsf!OpenDatabase&db=/GLOBAL/seapr/SEAPR035.NSF&v=a&e=us&m=V&c=4469737D59682F86C1256AAE002E2216	(indirect)
Labs for the 21st Century Energy Benchmarking	EPA/LBL	http://labs21.lbl.gov/bm.html	(indirect)
Labs for the 21st Century Design Intent Tool	EPA/LBL	http://ateam.lbl.gov/DesignIntent/home.html	(indirect)
One-2-Five	ENVINTA Corporation	http://www.one-2-five.com/	(indirect)
Snohomish County PUD	Benchmarking Tool	http://www.snopud.com/utility_entry.asp	(indirect)
Benchmarking System	ASIA-PACIFIC ECONOMIC COOPERATION	http://www.apecenergy.org.au/welcome/publications/benchmark.pdf	(indirect)
e-Energy	Building and Construction Authority of Singapore	http://www.bdg.nus.edu.sg/buildingEnergy/e_energy/commercial.html	(indirect)
e-Bench	Energy and Technical Services	http://www.energyts.com/	(indirect)
Performance Rating Calculator	Australian Building Greenhouse Rating	http://www.abgr.com.au/main.asp	(indirect)
Action Energy Survey	Action Energy by the Carbon Trust	http://www.actionenergy.org.uk/ActionEnergy/default.htm	(indirect)
GreenStar	Green Building Council of Australia	http://www.gbcaus.org/greenstar/page.asp?id=117	(indirect)
BREEAM	Building Research Establishment	http://products.bre.co.uk/breeam/index.html	(indirect)
Ecopoints	Building Research Establishment	http://www.bre.co.uk/pdf/076.pdf	(indirect)
Energy Benchmarking at the Company Level Within Industry Voluntary Agreements	European Commission Directorate-General XVII (Energy) in a SAVE Project	http://www.eva.ac.at/(en)/projekte/ideen2.htm	(indirect)
Higher Education Energy Benchmarking Tool	Building Research Establishment	http://www.solsticetrial.com/education/	(indirect)
On-line energy benchmarking	Target Energy Services	http://www.targ.co.uk/B__Index.htm	(indirect)
Energy Demand Profiler	Target Energy Services	http://www.targ.co.uk/H__Index.htm	(indirect)
E-Benchmark	New Buildings Institute	http://www.newbuildings.org/ABG.htm	google:building benchmark
Building America Research Benchmark	US DOE	http://www.eere.energy.gov/buildings/building_america/benchmark.shtml	google:building benchmark
EnerPro	EnerSys	http://www.energyprofiletool.com/ept_demo/scripts/main.asp	google:building energy benchmark

Table 3 (continued) – Initially Identified Commercial Protocols

Name	*Organization*	*URL*	*Found on Search*
BREEAM/Green Leaf	ECD Energy and Environment Canada	http://216.58.80.108/products/BREEAM%20GL/breeam_gl.html	(indirect)
HK-BEAM	Building Environment Council	http://www.bse.polyu.edu.hk/Research_Centre/BEP/hkbeam/main.html	(indirect)
Vykon E2 Profiler	Tridium	http://www.tridium.com/library/Profiler.pdf	google:building energy benchmark
ComFREE	Florida Solar Energy Center	http://energygauge.com/FlaCom/faq.htm#ComFREE	google: building energy rating
ASEAN ENERGY AWARDS	ASEAN	http://www.aseanenergy.org/energy_sector/energy_efficiency/aea/2002/evaluation_newexisting.htm	google:Building Energy Criteria OR Classification OR Merit
Commercial Green Building Program	City of Austin	http://www.ci.austin.tx.us/greenbuilder/comm_overview.htm	(indirect)
Earth Advantage Commercial Building	Portland General Electric	http://www.earthadvantage.com/commercial/about.asp	(indirect)
G/Rated - Portland LEED	City of Portland	http://www.green-rated.org/g_rated/grated.html	(indirect)
Minnesota Sustainable Design Guide	Hennepin County/Minnesota Office of Environmental Assistance	http://www.sustainabledesignguide.umn.edu/	(indirect)
LEED™ Supplement for King County	King County (Washington)	http://dnr.metrokc.gov/swd/leed/outline.asp	(indirect)
High Performance Building Guidelines	NYC Department of Design and Construction	http://www.ci.nyc.ny.us/html/ddc/html/ddcgreen/	(indirect)
GBTool	Natural Resources Canada/International Initiative for Sustainable Built Environment	http://iisbe.org/iisbe/gbc2k2/gbc2k2-start.htm	(indirect)
ENERGYguide Benchmark Module	Nexus Energy Software, Inc.	http://www.nexusenergy.com	(indirect)

Table 4 – Initially Identified Residential Protocols

Name	*Organization*	*URL*	*Found on Search*
EnergyGauge	Florida Solar Energy Center	http://energygauge.com/	google: building energy rating
ENERGY STAR Homes	EPA	http://www.energystar.gov/index.cfm?c=new_homes.hm_index	google: building energy rating
BEES	Alaska Housing Finance Corporation	http://www.ahfc.state.ak.us/Department_Files/RIC/Energy/bees/building-energy-efficiency-stand.htm	google: building energy rating
HERS	RESNET	http://www.fsec.ucf.edu/bldg/pubs/hers_meth/index.htm	(indirect)
NHER	NATIONAL ENERGY FOUNDATION (UK)	http://www.natenergy.org.uk/enrate2.htm	(indirect)
NatHERS	Australian and New Zealand Minerals and Energy Council	http://www.houseenergyrating.com/domestic.htm	google: building energy rating
California Home Energy Efficiency Rating System	California Energy Commission	http://www.cheers.org/	(indirect)
EnerGuide for Houses	Natural Resources Can.	http://oee.nrcan.gc.ca/houses-maisons/english/choice.cfm	(indirect)

Table 4 (continued) – Initially Identified Residential Protocols

Name	*Organization*	*URL*	*Found on Search*
Performance4 Home	Performance4	http://www.performance4.com/	(indirect)
HER	Sustainable Energy Ireland	http://www.irish-energy.ie/content/content.asp?section_id=507	google: building energy rating
Standard Assessment Procedure	BRE	http://projects.bre.co.uk/sap2001/	google: building energy rating
Green Built Home	Wisconsin Environmental Initiative	http://www.greenbuilthome.org/	(indirect)
Built Green	Home Builders Association of Kitsap County	http://www.kitsaphba.com/bbk.html	(indirect)
EarthCraft Houses	Greater Atlanta Home Builders Association	http://atlantahomebuilders.com/earthindex.html	(indirect)
Built Green Colorado	Home Builders Association of Metro Denver	http://www.builtgreen.org/shared/checklist.htm	(indirect)
BUILT GREEN	Master Builders Association of King and Snohomish Counties	http://www.builtgreen.net/	(indirect)
Green Home Standards	Florida Green Building Coalition	http://floridagreenbuilding.org/standard/homes/Default.htm	(indirect)
Green Points Program	City of Boulder	http://www.ci.boulder.co.us/environmentalaffairs/green_points/	(indirect)
Residential Green Building Program	City of Austin	http://www.ci.austin.tx.us/greenbuilder/programs_res.htm	(indirect)
Green Building Program	City of Scottsdale	http://www.ci.scottsdale.az.us/greenbuilding/	(indirect)
Earth Advantage Home	Portland General Electric	http://www.earthadvantage.com/homes/home/home.asp	(indirect)
G/Rated	City of Portland	http://www.green-rated.org/g_rated/grated.html	(indirect)
Build Green	Home Builders Association of Greater Kansas City	http://www.kchba.org/buildgreenkc/index.shtml	(indirect)
BuiltGreen	Building Industry Association of Hawaii	http://www.bia-hawaii.com/builtgreen/	(indirect)
California Green Builder Program	The Building Industry Institute	http://www.thebii.org/cgbp.asp	(indirect)
Vermont Built Green	Vermont's Building for Social Responsibility	http://www.bsr-vt.org/vermontbuiltgreenprogram.html	(indirect)
Green Home Choice Program	Arlington County Department of Environmental Services	http://www.co.arlington.va.us/des/epo/greenhome.htm	(indirect)
EnergyGauge	Florida Solar Energy Center	http://energygauge.com/	google: building energy rating
ENERGY STAR Homes	EPA	http://www.energystar.gov/index.cfm?c=new_homes.hm_index	google: building energy rating
BEES	Alaska Housing Finance Corporation	http://www.ahfc.state.ak.us/Department_Files/RIC/Energy/bees/building-energy-efficiency-stand.htm	google: building energy rating
HERS	RESNET	http://www.fsec.ucf.edu/bldg/pubs/hers_meth/index.htm	(indirect)

2.3.1 Categorizing and Describing Protocols

After the list was compiled, the remaining effort was focused on commercial (non-residential) protocols. Almost all of the residential protocols were based on points for specific building features usually with self-certification. The lesson learned is that point systems are easy to adopt, design to, and use. Point based protocols make sense for the home building community and have achieved a high degree of penetration.

The Project Monitoring Subcommittee (PMSC) was queried for the selection criteria that they favored prior to evaluating the protocols found. While many different criteria were considered, the PMSC determined that the following criteria were best suited for selecting the protocols:

- Use of, or reference to, ASHRAE products
- Range of approach
- Range of applicable building types
- Number of users.

An assessment, using these factors, was performed with an additional emphasis on whether documentation was available that would describe the protocol in detail.

Of the selection criteria, the number of users was the most difficult to identify since it is rarely described. When no estimate was provided, an impression of "few" or "many" was made based on intangibles such as web site quality, number of frequently asked questions, or existence of discussion forums, was made.

2.3.2 References to ASHRAE Documents

Of the commercial building energy performance rating protocols found, nine had references to ASHRAE publications such as standards, guidelines and the Handbook of Fundamentals. The correlation of a reference to ASHRAE for a point-based system (like LEED) is very high. This is because a point-based system is likely to reference specific requirements, almost like a standard.

ASHRAE publications referenced by the protocols included:

- Standard 29-1988 – Methods of Testing Automatic Ice Makers
- Standard 52.1-1992 – Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
- Standard 52.2-1999 – Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
- Standard 55-1992 – Thermal Environmental Conditions for Human Occupancy
- Standard 62-2001 – Ventilation for Acceptable Indoor Air Quality
- Standard 90.1-2001 – Energy Standard for Buildings Except Low-Rise Residential Buildings
- Standard 117-2002 – Method of Testing Closed Refrigerators
- Standard 129-1997 – Measuring Air Change Effectiveness
- Guideline 1-1996 – The HVAC Commissioning Process (G-1)
- Guideline 4-1993 – Preparation of Operating and Maintenance Documentation for Building Systems (G-4)
- ASHRAE Handbook – Fundamentals (HOF)

The use of these ASHRAE documents is shown in Table 5, below.

Table 5 – Use of ASHRAE Documents in Protocols

Protocol	*Standards*								*Guidelines*		*HOF*
	29	*52.1*	*52.2*	*55*	*62*	*90.1*	*117*	*129*	*G-1*	*G-4*	
LEED			x	x	x	x (99)		x			x
LEED-EB			x	x	x	x (99)		x			x
G/Rated - Portland LEED			x	x	x	x (99)		x			x
LEED™ Supplement for King County			x	x	x	x (99)		x			x
E-Benchmark	x			x	x	x	x				x
Minnesota Sustainable Design Guide			x	x	x(89)	x (89)			x	x	x
High Performance Building Guidelines				x (95)	x(89)				x	x	x
ENERGY STAR Label for Buildings		x		x	x(99)						
GBTool				x							x

Numbers in parenthesis are earlier versions of these documents where the number indicates the year.

The most common documents referenced are the Handbook of Fundamentals and Standards 55, 62 and 90.1. These documents are broadly accepted documents that are useful for all types of commercial buildings.

2.3.3 Buildings Explicitly Covered

Some of the building energy performance rating protocols may only be used to compare certain types of buildings while others are general and could support any type of building. For the protocols that do list specific buildings it is interesting to see how they categorize the building types (Table 6).

Table 6 – Building Classifications used in Protocols

Protocol	*Education*	*Healthcare*	*Hotel*	*Office*	*Retail*	*Warehouse*	*Other*
CALARCH	Education Education: K-12 Only	Health Care (Inpatient) Health Care (Outpatient) Nursing Home	Lodging (hotel, motel, dorm) Nursing Home	Office/Professional Other/Unknown	Enclosed Shopping Center/Mall Food Sales Food Services (restaurants) Retail (excluding mall)	Warehouse (refrigerated) Warehouse (non-refrigerated)	Agricultural Industrial Processing/Manufacturing Public Assembly Religious Worship
E-Benchmark	Schools	Medical and Clinics		Bank or Financial	Retail Stores	Industrial and Commercial Storage	Auditorium General Commercial Theaters
Earth Advantage Commercial Building	School/College Schools K-12	Health Care/Hospital Health Care/Clinic	Hotel/Motel	Office	Auto Sales/Service Grocery Retail	Warehouse/Storage	Assembly (church, theater, etc) Recreation/Fitness Restaurant Manufacturing
Action Energy Survey							Civil Estates
EMCOR Energy Edge	College Education (K-12)	Health (Inpatient) Health Care (outpatient) Nursing Home	Hotel	Office	Restaurant Retail (Non-Mall) Food Sales Service (excl food) Enclosed Shopping (Mall) Convenience Store Fast Food Strip Shopping	Warehouse Warehouse (refrigerated)	Laboratory Museum Public Assembly Public Order Religious Worship
Free Energy Benchmark	Education (School)	Health Care (Hospital)	Lodging (Hotel/Motel)	Office/Professional	Convenience Store Food Sales (Grocery) Food Services (Restaurants) Retail (Excluding Mall) Service (Excluding Food) Strip Mall	Warehouse (Non-refrigerated) Warehouse (Refrigerated)	
Commercial Building Incentive Program		Extended Care Hospital	Hotel	Office	Retail	Warehouse	Multi-family

Table 6 (continued) – Building Classifications used in Protocols

Protocol	*Education*	*Healthcare*	*Hotel*	*Office*	*Retail*	*Warehouse*	*Other*
e-Bench	Education	Heath					
Labs for the 21st Century Energy Benchmarking							Laboratories
ARCH	Education	Health Care (inpatient) Nursing Home Health Care (outpatient)	Lodging (hotel, motel, dorm)		Food Sales Food Services (restaurants) Service (excluding food) Strip Shopping Enclosed Shopping Center/Mall Retail (excluding mall)	Warehouse (refrigerated) Warehouse (non-refrigerated)	Laboratory Public Order and Safety Religious Worship Public Assembly
Performance Rating Calculator				Office			
GEM (UK)				Office			
Benchmarking System		Hospital	Hotel	Office			
EEBuildings			Hotels	Office Buildings			
ENERGY STAR Label for Buildings	K-12 Schools	Hospitals	Hotels	Office Buildings	Grocery Stores		
Online Benchmarking of Energy Consumption				Office Buildings	Retail Restaurant Supermarket		
Benchmarking Building Energy Performance	K-12 Schools Educational (all)	Health care (inpatient) Skilled nursing Health care (outpatient)	Lodging	Office	Food service Food sales Mercantile and service	Warehouse (non-refrigerated) Warehouse (refrigerated)	Public assembly Laboratory Parking garage Public order and safety
On-line energy benchmarking	School Further or higher education		Hotel	Office Bank, Post Office or agency	Store or shop Restaurant or fast food outlet		Industrial building Sports or recreation ▯ enter Entertainment building Library, museum or gallery
Green Globes				Office			Multi-family residential

Table 6 (continued) – Building Classifications used in Protocols

Protocol	*Education*	*Healthcare*	*Hotel*	*Office*	*Retail*	*Warehouse*	*Other*
Snohomish County PUD	School	Hospital	Hotel	Office	Retail Fast Food Restaurant Grocery	Warehouse	
BREEAM				Offices	Retail		Industrial
EnerPro	Elementary school Middle/high school	Extended care	Motel/Hotel	High-rise office (4 stories or more) Low-rise office (3 stories or less)	Stand-alone retail Strip mall Large mall Grocery store		
Power Smart e.Review	Primary school Secondary school	Extended care	Motel/Hotel	High-rise office (4 stories or more) Low-rise office (3 stories or less)	Stand-alone retail Strip mall Large mall Grocery store		
GBTool				Office	Retail		
ENERGYguide Benchmark Module	School	Medical Nursing Home	Hotel	Office Building	Auto Bakery Barber Shop/Salon Gas Station Grocery Health Club Laundry Printer Restaurant Retail	Small Warehouse	Funeral Home Religious Facility

2.3.4 Technical Approaches

The technical basis used for each of the protocols was identified by review of the website or technical documentation that was easily available. The original list had 49 commercial protocols but upon more thorough investigation seven were excluded. The exclusions were either because they did not apply to the buildings under consideration or did not actually have data to benchmark against. The remaining 42 were further subdivided into three groups:

- Technical Documentation Was Found and ASHRAE Reference (9)
- No ASHRAE Reference (13)
- No Technical Documentation Was Found (20)

The lack of some technical documentation creates an obstacle for the in depth evaluation of the rating methods. It does not necessarily mean they should be excluded from further investigation but simply that any technical information for these protocols that would be collected could not be confirmed in documentation.

The following tables (Table 7, Table 8, and Table 9) summarize the approach used by each of the three groups of protocols identified along with an estimate of the number of users. Recall that the number of users is based on a subjective impression and is classified simply as either "few" or "many" based on intangibles such as web site quality, number of frequently asked questions, and existence of discussion forums.

Table 7 – Approaches for Protocols with Documentation and ASHRAE References

Name	*Users*	*Summary*	*Notes*
LEED	Many	Points with prerequisites and reference building (via ECB in 90.1)	Points do not seem to equate directly with energy measurement (over 1000 registered projects)
LEED-EB	Few	Points with prerequisites and reference building (via ENERGY STAR Label)	
G/Rated - Portland LEED	Many	Points with prerequisites and reference building (via ECB in 90.1)	Based on LEED. Instead of 90.1 ECB method uses "Chapter 13, Energy Conservation, of the 1998 Oregon Structural Specialty Code (OSSC) with year 2000 amendments, as demonstrated by the Oregon whole building approach as referenced by Chapter 13 or Oregon Building Energy Performance Rating Method."
LEED™ Supplement for King County	Many	Points with prerequisites and reference building (via ECB in 90.1)	The LEED materials seem to be slightly modified and displayed in an interactive web site.
E-Benchmark	Few	Point with simulation based credit	Compare against building compliant with 90.1-2001 and must be 30% more efficient to get credit.
Minnesota Sustainable Design Guide	Many	Points and reference building	Similar to LEED. Points are scored for a variety of sustainable goals but for building energy performance uses simulation comparison of a building that exceeds 90.1-1989
High Performance Building Guidelines	Many	Points system with reference building comparison	Baseline is NY state energy code. Energy cost and energy use reduction targets based on comparison with baseline.
ENERGY STAR Label for Buildings	Many	Statistical	Uses CBECS as its data source
GBTool	Few	Points	Study for specific conference

Table 8 – Approaches for Protocols with Documentation

Name	*Users*	*Summary*	*Notes*
EEBuildings	Many	Statistical	CBECS, seems to be the same as ENERGY STAR Label for Buildings
Commercial Building Incentive Program	Many	Reference building	Questionnaire includes building thermal description but does not ask for energy consumption or cost
CALARCH	Few	Statistical	Sources of data include CEUS, NRNC Baseline Study, EPA, US GSA, Individual Buildings
EMCOR Energy Edge	Few	Statistical	CBECS for Benchmarking but DOE-2 simulation for "audit" portion
Labs for the 21st Century Energy Benchmarking	Few	Statistical	Very small set of data so more like "comparative"
Benchmarking System	Few	Statistical	1992 CBECS plus data for building in Asia-Pacific region
Performance Rating Calculator	Many	Unknown	Unknown basis for different EUI levels that correspond to different stars. Spreadsheet is available.
Action Energy Survey	Many	Reference building	Compare against a single reference building based on EUI
On-line energy benchmarking	Many	Reference building	Multiple reference buildings for typical and good practice. Measures are on carbon dioxide and annual energy cost per floor area.
EnerPro	Few	Simulation comparison	"The Energy Profile Tool (EnerPro) utilizes hundreds of model-based archetypes for its analysis. The archetypes are derived from thermal, hourly energy performance models using the DOE2.1e software and encompass more than 70,000 hourly simulations. Unlike most statistically based analysis approaches, EnerPro does not simply draw upon the relationship among easily quantifiable characteristics to predict energy savings. Instead, the EnerPro's engine derives its calculations from engineering practices and thermodynamic principles that are embodied in hourly energy performance simulations."
BREEAM/Green Leaf	Few	Points	Streamlined version of BREEAM
HK-BEAM	Few	Points with simulation based credit	Use specific simulation program to do comparison versus a baseline system that meets a set of prescriptive requirements.
ENERGYguide Benchmark Module	Many	Statistical	CBECS 1992 and 1995 databases. Adjusted by degree-days. Square foot and EUI adjustments based on building type.

Table 9 – Approaches for Protocols without Documentation

Name	*Users*	*Summary*	*Notes*
Benchmarking Building Energy Performance	Few	Statistical	Source EUI worksheet, CBECS. Note no documentation was found but reports are likely to be available.
Snohomish County PUD	Many	Reference building	Includes simple audit related questions about number of operating hours, updated lighting system, etc. Data from Bonneville Power Administration and the Northwest Power Planning Council. No documentation found but help system that is included is detailed.
Online Benchmarking of Energy Consumption	Many	Statistical	Little information provided.
Free Energy Benchmark	Many	Statistical	EUI and Energy Cost Index, BOMA and DOE data used, must register (user number was 1428 implying that many users).
Green Globes	Many	Statistical	Questionnaire includes ECM related questions. Related to BREEAM/Green Leaf and Canada's BOMA Earth Award. $250 per rating.
GEM (UK)	Many	Statistical	Questionnaire includes ECM related questions. Related to Green Globes
ARCH	Few	Statistical	Uses CBECS as its data source
CustomNet	Few	Direct comparison of multiple buildings	Uses several similar buildings all owned by user (such as a chain) and compares them
Power Smart e.Review	Few	Reference building	Series of energy use, ECM and design oriented questions. Results are shown versus a typical building and an energy efficient building. Includes recommended action plan.
Energy Profiler Online	Few	Unknown	Brochure does not describe any technical details
One-2-Five	Few	Statistical	Little information found except some sample reports for a typical building
e-Energy	Few	Statistical	Ranges in the statistics are assigned into different classes or levels.

Table 9 (continued) – Approaches for Protocols without Documentation

Name	*Users*	*Summary*	*Notes*
e-Bench	Many	Direct comparison of multiple buildings	Allows users to manage data collection process and identify multiple facilities, meters and space types. Many different graphs available. Compares against average of just a few other buildings in the same category. kWh/sqft and CO2/year-sqft (or per bed for hospital)
GreenStar	Many	Points energy based on stars in Australian Building Greenhouse Rating	Very similar to LEED program but no prerequisites.
BREEAM	Many	Point system with credit for reducing CO2 emissions based on baseline.	CO2 emissions are predicted and credits are awarded based on the percentage improvement over static ECON 19 benchmarks.
Higher Education Energy Benchmarking Tool	Few	Direct comparison of multiple buildings	List of eight universities and their energy usage. Focus is on pushing the energy costs down to the budgets of the departments in the university that use those buildings. Measures are not described but comparisons would be between a limited set of facilities.
Vykon E2 Profiler	Few	Direct comparison of multiple buildings	Designed for a large corporation that wants to compare the performance of a group of buildings to each other such as a chain restaurant or an owner of many office buildings.
ComFREE	Many	Simulation comparison	Uses DOE-2.1e for comparison to a reference building that meets the code. The software ComFree is only sold to certified raters.
Commercial Green Building Program	Few	Unknown	Very few details on web site, need to contact agency to get more details.
Earth Advantage Commercial Building	Few	Reference building	Stars for different percent saving ranges compared to code compliant building. Little information on web site, must contact people who run the program for more details.

2.4 Selection of Protocols

Midway through the effort, the project monitoring subcommittee chose the following ten protocols as an initial set to focus on:

1. LEED/LEED-EB
2. ENERGY STAR for Buildings
3. BREEAM or BREEAM/Greenleaf
4. ARCH/CALARCH
5. Emcor Energy Edge
6. EnerPro
7. ComFree
8. On Line Benchmarking
9. ENERGYguide
10. GBTool

The initial choices seemed to favor LEED/LEED-EB, ENERGY STAR for Buildings, and BREEAM, due to their wide spread adoption; ARCH/CALARCH because of its use of EUI that might demonstrate the advantages and disadvantages of using just EUIs. The others were chosen based on specific features that were of interest to the project monitoring subcommittee.

Upon further investigation, two of the protocols (Emcor Energy Edge and ComFree) were no longer being supported. ComFree was designed for an older version of the state energy code in Florida and since it is no longer consistent with the current version is no longer being supported. A new version of the software that is consistent with the Florida energy code has not yet been released. Emcor Energy Edge, while available, is not longer being maintained or actively marketed.

Because of several conference calls and e-mail exchanges over the course of the work, the project monitoring subcommittee chose the following five protocols as the final set. The reason for the selection is shown after each protocol.

1. LEED/LEED-EB – Selected due to its widespread adoption.
2. ENERGY STAR for Buildings – Selected due to its widespread adoption.
3. BREEAM – Selected due to its widespread adoption.
4. ARCH/CALARCH – Selected due its use of simple energy use intensity calculations.
5. ENERGYguide– Selected due to its business focus.

No endorsement by ASHRAE should be implied by the initial or final selection of the protocols. Some protocols were chosen due to a unique feature or approach that may or may not prove to be important for the project. No technical evaluation for the suitability of the protocols listed for any application was performed. No evaluation of the accuracy of the protocols listed was performed.

3 Identification of Buildings

3.1 Introduction

This section describes the identification of buildings that will be used to apply the five selected rating protocols in order to compare the results. Since the focus of this section is to gather data on actual buildings, the rating protocols or portions of the rating protocols related to new construction were not included. Since LEED-NC (formerly called LEED) is focused on new construction, it was not included in part of the analysis. The LEED-EB protocol includes points that are rewarded based on the score from the ENERGY STAR for Buildings protocol. In addition, portions of BREEAM are intended for use only during the design process so those portions were not included. The remaining portions of BREEAM that focus on existing building performance were included. Careful examination of the rating methods led to the approach described in the next section.

3.2 Approach

The original proposed approach was to use traditional data sources for building energy data such as:

- Texas A&M LoanStar
- Oak Ridge National Laboratory
- Energy Center of Wisconsin
- DOE High Performance Case Studies
- Northwest Energy Efficiency Alliance
- CEC Commercial End-Use Survey
- DOE/EIA Commercial Building Energy Consumption Survey

After reviewing the types of information needed for the point based protocols (LEED-EB and BREEAM) it was clear that getting information from the current building operator or facilities manager would become necessary. Because much of the building data from these traditional sources was at least a few years old, it was going to be difficult to track down the correct person to find out the information needed for these point based protocols. Due to this anticipated difficulty, the proposed approach for gathering building data was considered appropriate only if a new method did not find sufficient data meeting the criteria set out.

Instead of the proposed approach, a new approach was adopted which takes advantage of the public disclosure of the ratings that several of the rating methods allow. For many, one of the main reasons to perform a building rating is to indicate to peers, prospective clients, and others that the building performs better than average so a public disclosure is often desired. This means that contact information is sometimes available for those who are involved in determining the building's performance rating. For both LEED-EB and ENERGY STAR for Buildings, contact information is available from their respective web sites, www.usgbc.org and www.energystar.gov on many of the buildings receiving a rating. Contacts were selected and questionnaires were sent to them requesting that they complete and return them. Part of the questionnaire asks for permission to get energy and other data from the EPA and USGBC if appropriate. This minimizes the number of questions to only the most essential.

The reasons for using this new approach include:

- Rating systems cover many aspects of buildings not just utility energy consumption
- Existing building energy databases do not include answers to many questions
- Building contacts interested in supporting effort due to history of rating
- Actual rating serves as accuracy check

3.3 Questionnaire Development

The development of the questionnaires was done by first examining the different rating protocols. A combined list of what was needed by any of the protocols related to energy in existing buildings is shown in Table 10.

Table 10 - List of Data Needed

Data Needed	*Building Types*	*Units*
Type of building	All	
Name of building	All	
Point of contact person	All	
ZIP Code	All	Five digits
Location	Office, retail, grocery	
Gross floor area	All	sqft
Treated floor area	Office, retail, grocery	sqft
Monthly electric consumption	All	kWh
Monthly gas consumption	All	Therms
Monthly other fuel consumption	All	MMBtu
Annual electric consumption	All	kWh
Annual gas consumption	All	Therms
Annual other fuel consumption	All	MMBtu
Weekly operating hours	All	Hours
Number of occupants	Office	Count
Number of students	School	Count
Number of workers	Medical	Count
Main shift staffing	Grocery, warehouse	Count
Number of personal computers/ registers	Office,school, grocery	Count
Number of licensed beds	Hospital	Count
Number of floors	All	Count
Number of rooms	Hotels,dorms	Count
Number of months in operation	Schools	Count
Percent air-conditioned	All	Percent
Percent heated	All	Percent
Number of walk-in freezers/coolers	Grocery, warehouse	Count
Number of refrigerated/freezer cases	Grocery	Count
Presence of tertiary care	Hospital	Yes/No
Presence of above ground parking	Hospital	Yes/No
Presence of on-site cooking	School, hotel	Yes/No
Presence of mechanical ventilation	School	Yes/No
Presence of on-site cooking facilities	Grocery	Yes/No
Presence of HID or halogen lighting	Warehouse	Yes/No
Approximate age of facility	All	Years
Weekday opening time	All	Time
Weekday closing time	All	Time
Saturday opening time	All	Time
Saturday closing time	All	Time
Sunday opening time	All	Time
Sunday closing time	All	Time
Seaonality of business	All	Choice
Average cost per kWh	All	$/kWh
Average cost per Therm	All	$/Therm
Percent of use is off-site renewable	All	Percent
Percent of use is on-site renewable	All	Percent
LEED-EB EA Credits/ Prerequisites	All	List
Type of office	Office	Choice
Are end-uses submetered	Office	Yes/no
Are tenants submetered	Office	Yes/no
Losses minus gains for building fabric	Office	kWh/m2/year
Use of energy policy	Office	Yes/no
Energy audit every 3 years	Office	Yes/no
Information to occupants quarterly	Office	Yes/no
Energy/CO2 monitoring	Office	Yes/no
Energy/CO2 targetting	Office	Yes/no
Movement toward energy/CO2 target	Office	Yes/no
Maintenance schedule for heating and cooling	Office	Yes/no
Maintenance record for light fittings	Office	Yes/no

From this list, it was clear that some questions were only appropriate for certain buildings so questionnaires were developed for each of the major building types. The questionnaires were developed and provided to the PMSC for review and comment. Several good comments were received that increased the ease of completing the questionnaire. Perhaps the most important comment was to ask permission to get data from the EPA ENERGY STAR Rating for Building program instead of asking for the monthly energy consumption for electricity and natural gas. Since LEED-EB uses ENERGY STAR for one of the most important credits related to energy, this would be sufficient for all the people that were going to receive a questionnaire since they would participants with either LEED-EB or ENERGY STAR. In addition, questions related to LEED-EB did not need to be asked of those who participated in the LEED-EB program and instead permission was sought to get data from USGBC. Questions were simplified to a yes or no response whenever possible. The questionnaires were implemented in Microsoft Excel that enabled "pop up" help to appear and provide more details on each question and, a drop down list of possible responses. This approach made the questionnaires as short as possible. For LEED-EB participants, only an office building oriented questionnaire was created and distributed due to the high fraction of identified buildings that were office buildings. The questionnaires appear in Appendix A.

3.4 Survey Process

Four distinct surveys took place:

- LEED-EB Buildings
- ENERGY STAR Buildings Pilot
- ENERGY STAR Buildings Through EPA
- ENERGY STAR Schools

The surveys were not intended to be statistically valid but instead were used to gather enough example buildings to provide a useful demonstration of the variation in building energy performance rating protocols during the rating method testing portion of the project.

The LEED-EB survey was based on 72 different buildings described on the USGBC web site as participating in that program (as of May 2005). Of the 72 buildings, 46 were of office buildings and only a few others would be classified as one of the target buildings types. Due to this, only an office building questionnaire was developed for LEED-EB buildings and distributed. Reminders were sent out a few weeks after the original survey was distributed that increased the response rate slightly. Seven people completed the questionnaire and returned it. Many people that responded but did not complete the questionnaire said that their building had not yet completed the LEED-EB process or they decided that they were not going to complete the LEED-EB process. This is not surprising since the LEED-EB certification process is involved and can take substantial time to complete.

The ENERGY STAR database shows profiles for 372 buildings out of more than 2341 that have been labeled through the program as of July 2005. A profile is a more in-depth description from the EPA web site and includes contact information. In order to gauge the effectiveness of the questionnaire, a pilot survey was done focusing on just the hotel and hospital buildings with a public profile on the ENERGY STAR web site. The hospitals did not include the Veterans Administration hospitals with public profiles. Questionnaires were distributed to people representing three hotels and thirteen hospitals. Of these, representatives from one hotel and two hospitals completed the questionnaires and returned them.

The EPA generously offered to help with the survey by providing the cover letter on EPA letterhead encouraging participation in the survey. Due to this, it was felt that the response rate would be high enough to limit the number of contacts made to just 35 ENERGY STAR participants. The selection process used to choose these participants:

1) Included all 14 K-12 schools. One of the people who rated a K-12 school also did an office building so that was also included.

2) Included all of the hospitals that had the same points of contacts. This resulted in 20 hospitals but three points of contact.

3) Created an "overall score" for the buildings that is the sum of the following sub-scores.

a) Number of Years Rated. For 3 to 7 years of ratings, the score is 2. For 2 years of ratings the score is 1. For buildings rated only once the score is zero.

b) Latest Year Rated. For 2003 to 2005 the score is 2, for 2001 and 2002 the score is 1, for 1999 and 2000 the score is zero.

c) Number of Buildings by Point of Contact. If the point of contact had three or more buildings they get a score of 2, for two buildings the score is 1, for one building the score is zero.

4) The 55 buildings listed by a single person were not selected since that person has specifically asked the EPA not to be involved in any follow-on research.

5) Sorted previously unselected offices by ENERGY STAR building rating and then by the "overall score" since we wanted a distribution of ratings for the analysis but wanted to maximize that buildings that make up a score.

6) Select one building for each ENERGY STAR building rating from 75 to 100 (26 choices) with the highest "overall score". A good distribution from each census division was important.

7) Select other buildings rated by the same person.

This resulted in sending out requests to 35 people and requesting data on 78 buildings:

- 20 Hospitals
- 13 Schools
- 45 Offices

Unfortunately, while the response rate was higher than the LEED-EB and pilot ENERGY STAR survey, it resulted in only eight buildings worth of data from seven people. It is possible that by focusing on individuals who had rated multiple buildings that the extra burden of responding was enough to discourage wider participation.

The number of K-12 schools that had responded was fewer than the targeted number so additional steps were taken to try to get greater K-12 school participation. This last survey utilized the same questionnaire as the EPA assisted ENERGY STAR survey. A quick search of EPA’s web site concerning K-12 school districts that have “partnered” with EPA revealed eleven with contact information. Those were all contacted by phone and asked if they wanted to participate. Completed questionnaires were received for eight schools.

3.5 Selected Primary Buildings

The following table, Table 11, summarizes the buildings selected for testing the five energy performance rating protocols. As part of the questionnaire, an option for keeping the building and the person providing the data anonymous was provided. This option allowed people who may not have wanted public discussion of their building to still participate.

Table 11 – Selected Buildings

Type	*Census Division*	*Size(sqft)*	*Decade Built*	*Energy Code*
Hospital	East North Central	250,000	1940s	None
Hospital	West South Central	150,000	1990s	Unknown
Hospital	West North Central	450,000	1980s	Unknown
Hospital	Pacific	700,000	1970s	Unknown
Hotel	Mountain	50,000	1990s	Unknown
Office	South Atlantic	250,000	1960s	Unknown
Office	West North Central	150,000	1990s	Unknown
Office	East South Central	100,000	1960s	Unknown
Office	Mountain	250,000	1990s	90.1-99
Office	West South Central	300,000	2000s	90.1-89
Office	West South Central	250,000	1990s	90.1-89
Office	West South Central	650,000	2000s	90.1-89
Office	Mountain	750,000	1960s	Unknown
Office	Middle Atlantic	10,000	1990s	Local Energy Code
Office	Mountain	800,000	1980s	Unknown
Office	Pacific	300,000	1990s	Local Energy Code
Office	Pacific	950,000	2000s	Local Energy Code
Office	Pacific	450,000	1990s	90.1-89
Office	Middle Atlantic	750,000	1960s	Unknown
Office	Mountain	10,000	1990s	Local Energy Code
School	West North Central	150,000	1990s	Unknown
School	Middle Atlantic	50,000	1950s	None
School	Middle Atlantic	50,000	1960s	None
School	West North Central	50,000	1920s	Unknown
School	West North Central	50,000	1950s	Unknown
School	West North Central	150,000	1950s	Unknown
School	West North Central	50,000	1960s	Unknown
School	West North Central	50,000	1950s	Unknown
School	East North Central	500,000	1960s	None

Sizes rounded to nearest 50,000 sqft to keep data anonymous

All of these buildings were used during the evaluation applied to building energy performance rating protocols. Based on the original RFP this list of buildings exceeds each of the requirements listed in Table 12:

Table 12 – Meeting Requirements of RFP

Requirements of Buildings from RFP	*Actual Selected Buildings*
15 Buildings	29 Buildings
5 to 8 Offices (third to half of 15)	15 offices
5 K-12 Schools (third of 15)	9 K-12 schools
2 from hospital, lodging, restaurant, grocery, retail	5 (4 hospital, 1 lodging)
4 compliant with 90.1-89 or 90.1-99	9 code compliant (four 90.1-89, one 90.1-99, four other codes)

Some data has already been provided for these buildings and the remaining data will be provided by USGBC or EPA's ENERGY STAR program.

3.6 Supplementary Database

The Northwest Energy Efficiency Alliance performed a survey, mainly in 2001, of energy and energy characteristics for commercial buildings and published a report titled Assessment of the Commercial Building Stock in the Pacific Northwest (NWEEA 2004). Most of the buildings had been previously surveyed between 1987 and 1994 as part of various utility and government programs. This allowed comparison of some buildings over time. The public database from this survey contains data from 1157 commercial premises representing 2.4 billion square feet of floorspace. The tables below, Table 13 and Table 14, show the distribution of surveyed sites by building type and state.

Table 13 – NWEEA Commercial Building Stock Assessment

Building Type	*Number of Sites*
Dry Good Retail	177
Grocery	73
Office	247
Restaurant	72
Warehouse	125
Hospital	13
Hotel/Motel	43
Other Health	54
Other	180
School	79
University	59
Vacant	35

Table 14 – NWEEA Building Locations

State	*Number of Sites*
Idaho	105
Montana or Wyoming	49
Oregon	373
Washington	630

Since the survey looked at some of the same buildings in 1987 and in 2001, how the building type changed for specific building over that time is shown in the following table, Table 15. In general, most buildings continued to be used for the same purposes fourteen years after the original survey or else were now vacant.

Table 15 – Building Type Changes by Floor Space Over Time

Building Type 1987	*Percent Same Type 2001*	*Percent Vacant in 2001*
Dry Good Retail	86	4
Grocery	83	0
Office	94	1
Restaurant	79	13
Warehouse	73	12
Hospital	75	25
Hotel/Motel	100	0
Other Health	98	2
Other	79	8
School	100	0
University	100	0

The data from the survey provided a rich description of the buildings but the public data did not include some important items including monthly utility energy use, exact floor areas and exact locations. While these items were collected, they were removed from the public database to keep the identities of the individual buildings confidential. These data items were made available for this project.

To help understand the rating methods being examined in this project, buildings were selected based on two factors from the database.

- Billing data had to be based on actual bills and not on modeled results.
- Buildings were classified as hospital, office, school and hotel/motel.

These two criteria eliminated many buildings. The actual billing data requirement for both the electric and the gas utility consumption data (if gas was used) reduced the number of records selected from the database by 63%. Table 16 shows the number of buildings selected for four building types.

Table 16 – NWEEA Commercial Building Stock Assessment

Building Type	*Original Number of Sites*	*Number Selected*
Office	247	128
Hospital	13	3
Hotel/Motel	43	16
School	79	20

The resulting 167 buildings from the database of buildings, referred to as the supplementary buildings in the remainder of this report, were tested by some of the protocols. No permutations were performed on these supplementary buildings. Permutations were performed on the 29 primary buildings gathered directly during the project. This substantially added to the number of buildings being assessed and allowed for drawing of conclusions that are more general from the analysis.

4 ENERGY STAR for Buildings

4.1 Overview

The ENERGY STAR Label for Buildings program by the U.S. Environmental Protection Agency includes a building energy performance rating protocol based on matching the actual energy use of a building against a statistical distribution of buildings. The rating system is also being called the National Energy Performance Rating System. Anyone can go to the web site and use Portfolio Manager to benchmark their existing building performance without paying a fee.

http://www.energystar.gov/

The rating is described on a scale of 1 to 100 and a score of 75 or greater for a facility may make it eligible to receive the ENERGY STAR Label for Buildings. The score is based on where the building fits in the distribution of energy use for similar buildings based on source energy. It indicates the percent of comparable facilities nationwide that are less efficient. For most building types the data is from DOE/EIA's CBECS but data sets from EPRI and the Hospitality Research Group are used for hospitals and hotels, respectively.

As of October 2004, a tour of how the protocol works is available at:

https://www.energystar.gov/portfoliomanagertour/

A related tool Target Finder, intended for use during design, was not evaluated as part of this study.

4.1.1 Types of buildings

Currently the primary space types of buildings that may use the ENERGY STAR for Buildings protocol are:

- Offices (general offices, financial centers, bank branches, and courthouses)
- K-12 Schools
- Supermarkets/Grocery Stores
- Hospitals (Acute Care and Children's)
- Hotels/Motels
- Residence Halls/Dormitories
- Warehouses (refrigerated and non-refrigerated)
- Medical Offices

For some of these building types, some secondary spaces are allowed:

- Computer Data Centers
- Garages and Parking Lots
- Swimming Pools

Gross floor area is the measurement of building size that is used with the ENERGY STAR for Buildings protocol. Buildings with and without air conditioning can be assessed but they are all rated based on regressions from a database containing buildings which may or may not have air conditioning.

4.1.2 Location

The ENERGY STAR for Buildings protocol can be used throughout the United States and its territories since a zip code is the primary way of indicating location and climate. This implies that a building can be rated in any climate that occurs in the United States or in United States territories. The United States territories with ZIP Codes include:

- American Samoa

- Federated States of Micronesia
- Guam
- Northern Mariana Islands
- Puerto Rico
- U.S. Virgin Islands

In addition, Palau and Marshall Islands have U.S. ZIP code because they were once under U.S. administration.

While a building may be rated anywhere in the United States or in United States territories, the regression equations used in the rating process are based on actual buildings located in specific places. Due to this, ratings in some locations may do a poorer job of representing the fraction of buildings that use more energy.

4.1.3 Qualifications

To qualify to receive the ENERGY STAR Label for Buildings the following is required for all building types:

- At least 50% of the building floor space must be the primary space type selected.
- At least 11 full consecutive calendar months of user-entered data is present for all active meters in the facility. If there is more than one meter, these months must be overlapping.
- A minimum of 10 electrical meter entries between 15 and 45 days each over the 12 month evaluation period.
- If a data center is present, it can be no more than 10% of the gross floor area.
- If present, a garage cannot exceed the gross floor area of the entire building.

For offices, the minimum and maximum size depend on the type of office as shown in Table 17 below. In addition, the office building must operate at least 35 hours per week, have at least one computer and one occupant.

Table 17 - Office size qualification for ENERGY STAR Buildings

Office Type	*Minimum (sqft)*	*Maximum (sqft)*
General Administrative	5,000	10,000,000
Bank Branch	1,000	20,000
Financial Center	20,000	10,000,000
Courthouse	5,000	10,000,000

For hospitals, the gross floor area must be between 20,000 square feet and 5,000,000 square feet and no more than 40 floors. The hospital must at least 16 licensed beds and no more than 1,510 licensed beds.

For hotels/motels, the gross floor area must be between 5,000 square feet and 10,000,000 square feet. The average annual hotel/motel occupancy rate must be at least 45%. The requirements are summarized in Table 18.

Table 18 – Number of Room Requirement for Hotel/Motel in ENERGY STAR for Building

Type	*Minimum Rooms*	*Maximum Rooms*
Upper Upscale	20	2,500
Upscale	30	2,000
Midscale w/Food and Beverage	50	665
Midscale without Food and Beverage	40	320
Economy and Budget	20	700

Kindergarten to twelfth grade schools must be between 5,000 to 1,000,000 square feet. The building must be used primarily for academic instruction including:

- Kindergarten
- Elementary
- Junior High
- Senior High.

College or university classroom facilities and laboratories, and vocational, technical, and trade schools cannot be benchmarked at this time. The school building must be occupied at least 8 out of 12 months. The school building must operate at least 35 hours per week and have at least one computer and one occupant.

Medical offices must be between 5,000 square feet and 1,000,000 square feet. The medical office building must operate at least 35 hours per week, have at least one computer and at least two workers but no more than 3,500 workers.

Supermarkets and grocery stores must be between 5,000 and 250,000 square feet and no more three floors. The supermarket or grocery store must operate at least 35 hours per week. The main shift staff must be between 1 and 400 people. The store must have at least one refrigerator and freezer case, but no more than 350 refrigerated and freezer cases and no more than 35 can be walk-in. The store can have no more than 100 registers or personal computers.

Residence hall and dormitory spaces must be between 5,000 square feet and 1,000,000 square feet and contain from 5 to 800 rooms.

Refrigerated and unrefrigerated warehouses must be between 5,000 square feet and 1,000,000 square feet. The building must operate at least 40 hours per week and have no more than 4,000 workers and no more than 35 walk-in coolers and freezers.

To receive the actual label, a statement of energy performance must be signed and stamped by a registered professional engineer. The statement of energy performance reports the total energy use for electricity and each fuel, the rating, and all of the inputs to the rating. The statement of energy performance cannot be signed and stamped by a registered professional engineer until they verify the following:

- Thermal comfort is in accordance with the provisions in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 55-1992, Thermal Environmental Conditions for Human Occupancy (ASHRAE 1992).

- Indoor air quality is in accordance with the provisions of ASHRAE Standard 62-2001, Ventilation for Acceptable Indoor Air Quality (ASHRAE 2001).

- Illuminance levels are in accordance with the Illuminating Engineering Society of North America, IESNA Lighting Handbook - 1999, Lighting Design Guide (IESNA 2000).

In addition, the applicant must also sign a nomination letter concerning the building verifying the same requirements.

4.1.4 Audience

The number of inputs required to perform a rating using the ENERGY STAR for Buildings protocol is specifically limited to make it easy for a wide range of people to use the protocol. Almost anyone that would approve or manage the utilities bills for a building could successfully use the web site to obtain a rating. The additional information needed beyond the utility bills is floor area, number of occupants, working hours per week, etc. The protocol is clearly aimed at the building operator, facility manager or building owner. A professional engineer is hired to verify the information added and to ensure that the indoor environment is acceptable. Those involved in new building design such as developers or architects would not usually have access to actual metered energy use for a year but if they did, they could also use the protocol. It is also very unlikely that many designers have access to predictions of annual energy use and even if they did, they are often inaccurate.

4.1.5 Ease of Use

The building characteristics information required using the ENERGY STAR for Buildings protocol is shown in Table 19, below.

Table 19 – ENERGY STAR for Buildings Information Required

Information	*Offices*	*Schools*	*Grocery*	*Hospitals*	*Hotels*	*Dorms*	*Warehouses*	*Medical*
ZIP Code	x	x	x	x	x	x	x	x
Gross floor area	x	x	x	x	x	x	x	x
Weekly operating hours	x	x	x				x	x
Number of occupants	x							
Number of students		x						
Number of workers								x
Main shift staffing			x				x	
Number of personal computers/registers	x	x	x					
Number of licensed beds				x				
Number of floors			x	x				
Number of rooms					x	x		
Number of months in operation/year		x						
Percent air-conditioned		x				x	x	x
Percent heated		x				x	x	x
Number of walk-in freezers/coolers			x				x	
Number of refrigerated/freezer cases			x					
Presence of tertiary care				x				
Presence of above ground parking				x				
Presence of on-site cooking		x			x			
Presence of mechanical ventilation		x						
Presence of on-site cooking facilities			x					
Presence of HID or halogen lighting							x	

In general, the ENERGY STAR information requirements are ones that can easily be gathered while the building is in use without referencing building drawings or specifications. The most difficult to determine is the exact floor area and the fraction of the floorspace that is heated or air-conditioned. In addition to energy consumption data, between four and ten pieces of information about the facility is all that is needed to complete the benchmarking process, depending on the building type.

In addition, the monthly consumption is required for all meters:

- Electricity
- Natural gas
- Steam
- Propane
- Liquid propane
- Fuel oil (No. 2)
- Diesel oil (No. 2)
- Chilled water
- Wood
- Coal

The process provides guidance for the overall building performance only and does not go beyond benchmarking into evaluating the performance of individual building systems. The web site does include a great deal of information and resources to help building owners and operators reduce the energy consumption of the building including:

- Creating an action plan
- Training and motivating staff
- Building tune-ups
- Lighting
- Fan systems
- Heating and cooling systems
- Energy efficient products.

The rating can be performed through the "Portfolio Manager" on the EPA website related to ENERGY STAR programs for businesses. The process of entering the values needed is very simple and the display of results from the rating is easy to understand and may be customized. The energy consumption values shown appear to be site energy intensities but are not labeled as either source or site. Instead, they are labeled simply as "Actual Annual Energy Intensity." Several different views of the results from the rating are available by default including:

- Comparative (Initial/Current)
- Energy
- Environmental
- Facility Performance
- Financial
- Progress
- Status

In addition, alternative views can be created by the user, which include:

- Rating (1-100) (Benchmark Results)
- Target Rating (Benchmark Results)
- Current Annual Energy Intensity (Comparative) kBtu/Sq. Ft.
- Current Period (Comparative)
- Current Rating (Comparative)
- Initial Annual Energy Intensity (Comparative) kBtu/Sq. Ft.
- Initial Period (Comparative)
- Initial Rating (Comparative)
- Actual Annual Energy Intensity (Energy Use) kBtu/Sq. Ft.
- Annual Energy Intensity (for Avg. Rating of 50) (Energy Use) kBtu/Sq. Ft.
- Energy Savings (Energy Use) kBtu (thousand Btu)
- Energy Savings per Sq. Ft. (Energy Use) kBtu/Sq. Ft.
- Energy Use Alerts (Energy Use)
- Period Ending (Energy Use)
- Total Energy Use (Energy Use) kBtu (thousand Btu)
- CO_2 Reduced (Environmental) Lbs. (pounds)
- NO_x Reduced (Environmental) Lbs. (pounds)
- SO_x Reduced (Environmental) Lbs. (pounds)
- Annual Energy Cost (Financial) US Dollars ($)
- Cumulative Investment (Financial) US Dollars ($)
- Cumulative Investment per Sq. Ft. (Financial) US Dollars ($)
- Total Energy Cost per Sq. Ft. (Financial) US Dollars ($)
- Building Owner (Organizations)
- Service and Product Provider (Organizations)

- Zip Code (Organizations)
- Building Type (Space Use)
- Number of Occupants (Space Use)
- Number of Students (Space Use)
- Space Use Alerts (Space Use)
- Total Floor Space (Space Use) Sq. Ft.
- Building Profile Status (Status)
- Full Year (Status)
- Label Application Status (Status)
- Last Modified (Status)

Multiple facilities can be individually entered and managed overall as a "portfolio." Summary pages provide the ratings of all buildings next to each other along with other views. Facilities can input meter information on an on-going basis to see how their rating changes with time. This is a good approach so that energy retrofit impacts can be tracked. Overall, the output reporting capabilities are quite comprehensive. No graphical depiction is shown for the energy use of the building as part of a distribution of buildings.

Meter data may be downloaded after entered from the web site. If meter data is already in a spreadsheet, it may be uploaded to the web site.

A target value for energy consumption may be shown as a goal for the user. A "Statement of Energy Performance" can be generated on site and the steps needed to get a label are made clear. A downloadable PDF version of the Statement of Energy Performance is also available although the download link launches a script rather than being a hard link to a file – this may cause problems with some Internet browsers.

To receive a benchmark score, the user must create an account. The user's name and email address is required and the zip code of the facility is required. No confirmation of the email address or user name is required so someone very concerned about their privacy could create fictitious accounts.

If utility bills for the last twelve months are in hand, the entire process takes about half an hour including looking at the results.

Overall, the Portfolio Manager could easily satisfy all the needs for a building owner or operator as an energy analysis tool. The web site could be successfully used by anyone familiar with the building and its utility bills. The site is in English, no other language appears to be supported.

4.1.6 Use Statistics

During the first year of the ENERGY STAR for Buildings program, 1000 users assessed the performance of over 2000 buildings. Of the 2000 office buildings, 90 earned the ENERGY STAR for Buildings Label (Hicks 2000a). In a more recent brochure (EPA 2002a), 729 buildings had earned the ENERGY STAR for Buildings Label. Of the 729, 436 were office buildings, 287 were schools, 3 were hospitals, and 3 were supermarkets. Of the 436 office buildings, investors owned approximately half, governments owned a quarter, and owners occupied a quarter. In addition, 85% of the labeled buildings use an energy management system, 50% utilize motion sensors for lighting systems, and 99% report that they perform regular operation and maintenance. The 287 schools were concentrated in one-dozen school districts making statistical comparisons against other surveys difficult (Von Neida 2001). By the end of 2001, 475 offices were certified with the ENERGY STAR for Buildings Label. Since the ENERGY STAR building operators choose to participate, the self-selection bias must be considered when interpreting the statistics. The office buildings totaled over 148 million square feet of gross floor area and represented 33 states and the District of Columbia. A recent press release containing statistics from March 10, 2004 states:

> *As of January 1, close to 1,400 of the nation's most energy efficient buildings, representing about 325 million square feet, have earned EPA's ENERGY STAR designation for superior energy performance. The buildings qualifying as ENERGY STAR use about 40 percent less energy than average buildings without compromising*

comfort or services. Among the top performing buildings are 791 offices and 375 public schools. Supermarkets, hospitals and hotels account for another 221 labeled buildings. These buildings can be found in 47 states and the District of Columbia. California, Colorado, North Carolina and Texas each have over 75 ENERGY STAR qualifying buildings. In 2003, almost 500 buildings were labeled, the most in any year since certification began. Buildings earn the ENERGY STAR by scoring a 75 or higher on EPA's 100-point national energy rating scale. The average of all buildings qualifying for ENERGY STAR through 2003 is 84.

The following table, Table 20, is based on recent annual reports from the ENERGY STAR program of EPA (EPA 2001, EPA 2002b, EPA 2003, EPA 2004).

Table 20 - Cumulative Use of ENERGY STAR for Buildings

Through Year	*Cumulative Users*	*Cumulative Assessed Buildings*	*Cumulative Assessed Floorspace (million sqft)*	*Cumulative Labeled Buildings*	*Cumulative Labeled Floorspace (million sqft)*
1999	1,000	2,000		90	
2000		4,200		545	
2001		14,200		726	
2002		15,000	2,500	1,100	
2003	3,500	19,000	3,200	1,400	325

For office buildings over 50,000 sqft, the average size for ENERGY STAR labeled buildings was 350,000 sqft while the CBECS average was 130,000 sqft. The ENERGY STAR building size is significantly larger than the average CBECS size and may indicate a bias toward larger buildings when trying to obtain a public recognition goal.

4.1.7 History

The ENERGY STAR for Buildings rating protocol was first made publicly available in 1999. At that time it only covered office buildings. Other building types have been added gradually. In addition, the protocol has incorporated revised data and was updated. The database used to derive the office protocol was originally the DOE/EIA CBECS data from 1992 and 1995, later it was revised to be based on the CBECS data from 1999. The user interface on the web site has been updated to increase the flexibility and features. Overall, the algorithm used in the protocol has remained largely unchanged although it has been adapted for each successive building type.

4.1.8 Rating Cost

A rating using the ENERGY STAR for Buildings rating method is free. In addition, the EPA does not charge for the application process of getting an ENERGY STAR for Building Label. Part of the process does require a professional engineer to certify the inputs to the model and to make sure the building conditions for the occupants are acceptable. The cost of that service depends on the engineer hired but EPA provides an estimate for these services of $0.005 to $0.01 per gross square foot. This estimate seems very low for a small building but may be appropriate for a large building.

4.2 Technical Basis

4.2.1 Empirical Data

The ENERGY STAR for Buildings energy performance rating protocol is based on empirical data. The following table, Table 21, summarizes the use of the data.

Table 21 – Data Sources and Number of Records

Building	*Data Source*	*# Records*	*#Filtered Records*
Offices	CBECS 1999	1125	910
K-12 Schools	CBECS 1999	481	400
Grocery	CBECS 1992/1995	194	88
Hospitals	EPRI 1997	701	493
Hotels/Motels	HRG 1999	2915	705
Dorms	CBECS 1999	81	79
Warehouses	CBECS 1999	722	579
Medical office	CBECS 1999	93	82

Most of the building types were based on the U.S. Department of Energy, Energy Information Administrations, Commercial Building Energy Consumption Survey (CBECS). The CBECS database and reports based on the database are available at no charge from the www.eia.doe.gov web site. The CBECS database is updated every four years and covers the United States. The CBECS database survey was first conducted in 1979 and subsequent surveys were conducted in 1983, 1986, 1989, 1992, 1995, 1999 and their most recent was in 2003. They fully disclose their survey methodology and provide extensive documentation. It is clearly one of the best building energy databases available. The survey methodology is described as:

> *The CBECS is conducted in two data-collection stages: a Building Characteristics Survey and an Energy Suppliers Survey. (For the 1999 CBECS, the Energy Suppliers Survey was initiated only if the respondents to the Building Characteristics Survey could not provide the energy consumption and expenditures information.) The Building Characteristics Survey collects information about selected commercial buildings through voluntary interviews with the buildings' owners, managers, or tenants. In the 1999 survey, these data were collected using Computer-Assisted Telephone Interviewing (CATI) techniques. (In previous CBECS cycles, the information was collected during personal interviews.)*
>
> *During the Building Characteristics Survey, respondents are asked questions about the building size, how the building is used, types of energy-using equipment and conservation measures that are present in the building, the types of energy sources used, and for the 1999 survey, the amount and cost of energy used in the building. Building respondents could provide the consumption and expenditures information for approximately 60 percent of the sampled buildings. For the remaining 40 percent of buildings, the energy supplier names, addresses and account numbers were obtained.*
>
> *Upon completion of the Building Characteristics Survey, the Energy Suppliers Survey is initiated for those cases that did not provide consumption and expenditures information. This Suppliers Survey obtains data about the building's actual consumption of and expenditures for energy from records maintained by energy suppliers. These billing data are collected in a mail survey conducted under EIA's mandatory data collection authority. A survey research firm, under contract to EIA, conducts both the interviews for the Building Characteristics Survey and the mail survey for the Energy Suppliers Survey (http://www.eia.doe.gov/emeu/cbecs/howconducted.html).*

The CBECS database includes a field that describes the principal building activity (asterisk indicates its use in by ENERGY STAR).

- Administrative/Professional office*
- Auto dealership/Showroom
- Auto service/Auto repair

- Bank/Financial*
- Clinic/Outpatient health
- College/University
- Courthouse/Probation office*
- Doctor/Dentist office*
- Dormitory/Fraternity/Sorority*
- Dry cleaner/Laundromat
- Elementary/Middle/High school*
- Enclosed mall
- Entertainment (Theater/Sports arena/Nightclub)
- Fire station/Police station
- Government office*
- Grocery store/Food market*
- Hospital/Inpatient health
- Hotel
- Jail/Reformatory/Penitentiary
- Laboratory
- Library/Museum
- Motel/Inn/Resort
- Non-refrigerated warehouse*
- Nursing home/Assisted living
- Other education
- Other food sales or service
- Other health care
- Other lodging
- Other office*
- Other public assembly
- Other public order and safety
- Other retail
- Other service
- Post office/Postal center
- Preschool/Daycare
- Recreation (Gymnasium/Bowling alley/Health club)
- Refrigerated warehouse*
- Religious worship
- Repair shop
- Restaurant/Bar/Fast food/Cafeteria
- Social meeting center/Convention center
- Store
- Strip shopping center
- Vacant
- Other

The Electric Power Research Institute (EPRI) database is called the Energy Benchmarking Survey, which does not appear to be publicly available although it is referenced in another report (EPRI 1997). The EPRI database does not appear to be maintained. Very little is known about this database.

The Hospitality Research Group (HRG) database is used in a report titled Trends in the Hotel Industry (HRG 2004) but the database itself is not publicly available. The 1999 version of the report is no longer being sold. The HRG database appears to be updated annually. The EPA contracted with HRG to process the data specifically to provide information for benchmarking models. The HRG database has been gathered annually for almost 100 years. While they do not disclose the details, given that members of hotel industries are their clients, the database is presumed to be highly reliable. The survey is conducted with hotels and motels throughout the United States and the report generated from the database includes information on major market cities. The financial data gathered includes annual utility costs for each utility serving the hotel. It is not clear whether utility energy consumption is actually gathered as part of the survey or would need to be derived based on energy cost. The hotels are individually classified into one of nine categories based on Bear Stearns and Company categories:

- Deluxe
- Luxury
- Upscale
- Midscale with food and beverage
- Midscale without food and beverage
- Economy
- Budget
- Extended Stay High
- Extended Stay Low

For the ENERGY STAR benchmarking database, some of these categories were combined or eliminated. Deluxe and Luxury were combined. Economy and Budget were combined. The two extended stay categories were eliminated because they contained only a few records.

Although not explicitly stated, all three databases are snapshots of the current population of those respective buildings.

Each database was filtered to get rid of anomalous records and create a database that appears more homogenous. The filters for each are shown in the following table, Table 22.

Table 22 – Filters Used with Database

Building	*Filter Variable*	*Criteria*
Offices	Gross building area	5000<x (1000<x banks)
	Weekly hours of use	30<x
	#Months per year	10<x
	Occupant density	0.3<x<10.0
	#Personal computers	0<=x
	Source energy intensity	42.67<x<731.2
K-12 Schools	Gross building area	4,999<x<900,000
	Weekly hours of use	30<x<168
	#Months per year	8<x
	Cost per MMBtu	$1.5<x
	Classroom seating capacity	x<10,000
	Source energy intensity	37.3<x<314.8
Grocery	Gross building area	4,999<x<1,000,000
	Weekly hours of use	29<x
	#Months per year	10<x
	Electric consumption	0<x<10,000,000,000,000
	Heating plus cooling degree-days	0<x
	Food sales percentage	89<x
Hospitals	Complete records	N/A
Hotels/Motels	Complete records for non-extended stay	N/A
Dorms	Source energy intensity	40<x<425
Warehouses	Gross building area	4,999<x<1,000,000
	Weekly hours of use	35<x
	#Months per year	10<x
	Electricity used	0<x
Medical office	Weekly hours of use	30<x<168
	Number of workers	1<x
	Source energy intensity	38<x<575

The use of source energy intensity as a filter could be misconstrued. Since that is the dependent variable in the analysis, limiting the records to only those within a given range could introduce a bias in the results. If it is used as a filter variable, explanation should be provided to show that it does not bias the results. It may be that the filters are used to remove questionable data, which if it remained in the database would likely bias the results more.

4.2.2 Use of ASHRAE standards

Receiving a rating using the ENERGY STAR for Building web site (Portfolio Manager) is performed without any reference to ASHRAE standards; however, to actually receive a label, a professional engineer must be hired to certify that the building meets four indoor environmental criteria:

- Indoor pollution controlled
- Adequate ventilation provided
- Thermal conditions met
- Adequate illumination provided

The first three are based on meeting ASHRAE standards and the last on Illuminating Engineering Society of North America's Lighting Handbook (IESNA 2000). To ensure that the building is comfortable for the occupants the building should comply with the requirements of ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy (ASHRAE 1992). The EPA produced Professional Engineer's Guide (EPA 2003b) specifically states:

> *The assessment of thermal comfort should take into account all measurements and observations, and does not depend upon one occupied space not meeting the temperature and humidity requirements. After considering all measured data and observations, it is the responsibility of the PE to determine whether the building meets the letter and spirit of ASHRAE Standard 55.*

To ensure that adequate ventilation is provided and that indoor air pollution is controlled, the building should comply with ASHRAE Standard 62-1999 (ASHRAE 1999). Healthcare facilities may meet the requirements of Standard 62 or the AIA Guideline for Design and Construction of Hospitals and Healthcare Facilities (AIA 2001).

In addition, not all spaces need to be surveyed. This allows the professional engineer to more easily assess if the building can receive the label while focusing their efforts on making sure the building is not abusing the labeling system by ignoring the indoor environment.

Furthermore, although not referenced as a requirement, the Professional Engineer's Guide (EPA 2003b) in the section on indoor air pollutants under the "Hints and Tips" subsection, suggests reviewing ASHRAE Standard 52.1 Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter (ASHRAE 1992b).

4.2.3 Documentation available

The documentation that is available from EPA concerning the ENERGY STAR Label for Buildings rating method is quite extensive. The documentation includes support for improving energy efficiency in buildings that don't qualify for the label (EPA 2001e) as well as extensive technical reports with enough level of detail to be able to replicate the rating methodology.

The technical documents that have helped form the basis for this report are available at no charge on EPA's web site and they include:

- ENERGY STAR Label for Buildings Technical Description (EPA 1999)
- Technical Description for the Hotel/Motel Model (EPA 2001b)
- Technical Description for the Grocery Store/Supermarket Model (EPA 2001c)
- Technical Description for the Hospital Model (EPA 2001d)
- Technical Description for the Office, Bank, Financial Center, and Courthouse Model (EPA 2003c)
- Technical Description for the K-12 Model (EPA 2003d)
- Technical Description for the Warehouse Model (EPA 2003e)
- Technical Description for the Medical Office Building Model (EPA 2004b)
- Technical Description for the Residence Hall/Dormitory Building Model (EPA 2004c)
- Benchmarking Commercial Building Performance: "Site" and "Source" Energy (EPA 2001f)
- Professional Engineer's Guide to the ENERGY STAR Label for Buildings (EPA 2003b).

Many other pieces of information were gathered from the ENERGY STAR web site directly including details on weather normalization. In addition, the following papers have also served to provide context and understanding of the ENERGY STAR Label for Building protocol:

- An Evaluation of America's first ENERGY STAR Buildings: The class of 1999 (Hicks 2000a)
- U.S. National Energy Performance Rating System and ENERGY STAR Building Certification Program (Hicks 2004)

- Building Performance Defined: the ENERGY STAR National Energy Performance Rating System (Von Neida 2001)
- The ENERGY STAR Building Label: Building Performance through Benchmarking and Recognition (Hicks 1998)
- Implications of Ownership: An Exploration of the Class of 1999 ENERGY STAR Buildings (Janda 2000).

Other publications are available that deal less with the description of the technical basis of the system and more with how to apply the label.

4.2.4 Calculation details

The most complete description of the calculation details for the ENERGY STAR Label for Building rating method is described in the preceding section on available documentation and written by EPA. While this section summarizes the calculation steps, it should not be considered a substitute for reading the appropriate technical model description provided by the EPA.

The dependent variable for all building types is a natural logarithm of source energy. The source energy is computed based on the following factors in Table 23.

Table 23 – Source Energy Multipliers

Fuel Type	*Source Energy Multiplier*
Electricity	3.013
Natural Gas	1.024
Fuel Oil	1
Steam	1.38
Hot Water	1

The source of the conversion factors is not discussed but the values for electricity and natural gas, the primary types of energy consumption in commercial buildings, seem reasonable. The fuel oil and hot water multipliers appear to be too low. In the case of hot water, since fuel is usually consumed in the production of hot water, the multiplier should be at least the value of the natural gas multiplier. Further, losses from distributing hot water would imply an even greater value. For fuel oil, its distribution by truck and its processing in a refinery mean that more energy is used prior to delivery to the customer, and therefore its value should also be greater than one. On-site renewable energy reduces the amount of energy consumed from the utilities so it does directly affect the rating. Off-site renewable energy is not part of the rating process since the source energy multiplier cannot be changed. If the building is served by multiple meters, they are added together to form the total building source energy consumption. Sub-metering, for a single end-use or part of a building, is not used by the rating method. It is not clear how a building that used district chilled water would be evaluated.

The independent variables examined in the statistical analysis of the data are shown in Table 24.

Table 24 – Examined Independent Variables

Building	*Variables*	
Offices	Heating degree-days*	Natural log of weekly hours of use*
	Cooling degree-days*	Indicator of bank*
	Natural log of #workers*	Indicator of financial center*
	Natural log of #computers*	Indicator of courthouse*
	Natural log of gross building area*	
K-12 Schools	Heating degree-days times percent heated*	Presence of cooking area**
	Cooling degree-days times percent cooled*	Natural log of hours/week >50% occupied**
	Natural log of #computers*	#Months per year**
	Natural log of gross building area*	Indicator of mechanical ventilation*
	Natural log of classroom seating capacity*	
Grocery	Natural log of heating degree-days**	#Months per year
	Natural log of cooling degree-days**	Natural log of #Workers*
	Total degree-days	Worker density
	Percent cooled	Natural log of #floors*
	Percent heated	#walk in freezers or refrigerators
	#Computers or registers**	#open refrigerator cases
	Natural log of gross building area*	#closed refrigerator cases
	Presence of cooling	Natural log of #total refrigeration units
	Presence of cooking area**	Number of attached walls
	Natural log of weekly hours of use**	Presence of high hot water demand area
	Natural log of #floors*	
Hospitals	Heating degree-days	Indicator of tertiary care*
	Cooling degree-days	Indicator of above ground parking*
	Total degree-days*	Indicator of on-site laundry
	Natural log of gross building area*	Indicator of on-site food service
	Natural log of #beds*	Indicator of MRI facilities
	Natural log of #floors*	Indicator of radiation therapy
	Natural log of #employees	Indicator of swimming pool
	Indicator of acute care/children*	Indicator of teaching hospital
Hotels/Motels	Natural log of heating degree-days	Natural log of #guest rooms*
	Natural log of cooling degree-days	Indicator of food, beverage or banquet*
	Natural log of total degree-days*	
Dorms	Heating degree-days times percent heated*	Natural log of gross building area*
	Cooling degree-days times percent cooled*	Natural log of #sleeping rooms**
Warehouses	Indicator if refrigerated*	Cooling degree-days times percent cooled*
	Total number of walk in refrigerators*	Natural log of #workers*
	Natural log of gross building area*	Natural log of weekly hours of use*
	Heating degree-days times percent heated*	Percent lit by HID or halogen*
Medical office	Heating degree-days times percent heated**	Natural log of #workers*
	Cooling degree-days times percent cooled*	Natural log of weekly hours of use**
	Natural log of gross building area*	

* Indicates left in model due to t-Statistics of better than +/- 2.0
** Indicates left in model due to strong preference by users

The great variety of building variables is appropriate given the difference in important drivers for different types of buildings. What is unusual is that common variables such as heating and cooling degree-days appear in different forms. For some types of buildings, offices and hospitals, the heating and cooling degree-day variables are directly in the model, unmodified. For other buildings, the natural logarithm of heating degree-days and the natural logarithm of cooling degree-days are in the model (grocery and hotel/motel). For still other buildings, the heating degree-day is multiplied by the percent of the heated floorspace and the cooling degree-day is multiplied by the percent of cooled floorspace as variables in the models (K-12, dorms, warehouses, medical offices). This type of variation of how variables are included in the different building type models is repeated for other variables also. This variation can be explained based on either the evolution of approaches as new building types were added to the ENERGY STAR for Buildings list or by tenacity on the part of analysts looking for different combinations and manipulations of the variables to get the best fit to the model. Either way, it is a good lesson that future analysts should be open to using different forms or combinations of variables for different buildings in order to obtain the best fit for the model as possible.

To understand the relative importance of building floor area, the regression models were first examined based on floor area only as shown in Table 25.

Table 25 – Measure of Model Fit

Building	*Floor Area Only Model R^2*	*Full Model R^2*
Offices	0.91	0.93
K-12 Schools	0.85	0.87
Grocery	0.63	0.79
Hospitals	Not shown	0.83
Hotels/Motels	Not shown	0.60 to 0.88
Dorms	0.86	0.88
Warehouses	Not shown	0.80
Medical office	0.91	0.93

The previous table indicates the R^2, which is a measure of how well the multiple regression model fit the data, for the complete model and one that are based on floor area only. In general, for building types with both figures, the addition of other variables after the floor area increased regression fit minimally, except in the case of grocery. This result is somewhat counter intuitive. Normally we would expect that many different factors affect energy consumption in buildings including the variables added to the model. Since this is a statistical sample, what is not shown are the many real world impacts of other unknown parameters of the surveyed buildings, such as the actual variation in occupancy, the level of insulation, and the type of glass. Of course, it is also possible that the model formulation is poor and that these variables would impact the model more if the formulation of the model was different. Since the impact of each parameter is very small, the inclusion of just a few is bound to only improve the accuracy of the model a small amount.

The criterion for keeping a variable in the model was when the T-stat is better than +/- 2.0. Some additional variables were kept in the model because users expected a dependency on them even if their impact was less than T-stat +/- 2.0.

The hotels were actually modeled as five different multiple linear regressions, one for each class of hotel. The variables shown as included were not included in all of the hotel models.

The model is then applied to the filtered records from the CBECS, EPRI, or HRG database, as appropriate, to calculate the Predicted Source Energy consumption for each record. This is done to normalize the data and smoothes the results so they don't show as much random variation at the individual record level. These are then put into a histogram and values that correspond to the thresholds for each percentage point 1%, 2%, 3%, .., 100% are computed and are called Predicted Source Energy Thresholds (normalized curve). These values are then fit to a gamma distribution to further smooth out the values keeping the 75% value constant during the fitting so that it does not affect who is eligible to receive the ENERGY STAR Label. The reason stated for this step of fitting the data to a gamma distribution is to reduce the clustering of results that may result in a small change in source energy making a multiple point change in score. This step removes any "jaggies" that can result from a model that is based on a limited number of data points. This was stated to be an issue for beta test users. The values after the application of the gamma fit are called Fitted Source Energy Thresholds. The Fitted Source Energy Thresholds are still in the form of values corresponding to 1%, 2%, 3% all the way to 100% in 1% increments. The increments correspond to the Energy Performance Rating values of 1 to 100.

Two different steps in the process to increase smoothing, using the model to compute the Predicted Source Energy for each record and the application of a gamma function to compute Fitted Source Energy seems unnecessary. The gamma fit alone would probably result in a smooth curve. The risk of two different steps to promote smoothing is that is reduces variation and may artificially affect the energy consumption variation.

All of the preceding calculations were performed for each building type once and stored for retrieval as the "base normalized comparison curve" when a user requests an energy performance rating. The variables that the regression models use are the same as the inputs provided by the user. Each independent variable in the model has some type of input from the user. In some cases such as heating and cooling degree-days, the user provides a zip code and date range and a database of average temperatures for locations throughout the United States is accessed to compute the degree-days. The model provides an "adjusted normalized" result specific to the user values for each individual building.

The user inputs monthly electricity and fuel consumption based on metered energy use from utility bills. These are converted into annual source energy using the same multiplier as was used in the database processing, see Table 23. The user provided source energy consumption is then normalized for weather to make the energy use reflect a 30-year average resulting in the Weather Normalized Use. This is because the same building may experience significantly different weather from year to year and the label should apply to its expected typical performance. The weather normalization method was developed by Dr. Kelly Kissock of the University of Dayton and is described on the EPA web site and is quoted below (EPA 2004f):

1. *Based on its zip code, a building's monthly electricity consumption is regressed against the corresponding monthly average daily temperatures for that area to determine the building's response to the actual weather conditions experienced.*
2. *If one month's electricity consumption is significantly different from the building's average monthly consumption (i.e., at least 50% higher or lower than the mean), that month's value is not included in the regression analysis.*
3. *Based on the results of the regression analysis, historical, 30-year average values for monthly average temperatures are then used to normalize the building's actual 12-month electricity consumption data up or down.*
4. *Steps 1 and 3 are repeated for non-electric energy consumption - specifically just natural gas and district steam - to normalize the building's actual 12-month non-electric energy consumption up or down. The outlier test in Step 2 above is not performed for non-electric fuels since usage of these fuels often varies widely over the course of a year. Also, weather normalization on non-electric fuels other than natural gas or steam is not attempted since actual monthly consumption is typically not precisely known. Nonetheless, consumption of non-electric fuels other than natural gas or steam (i.e. fuel oil) is collected and included as part of the building's total energy use within Portfolio Manager.*
5. *The normalized electricity and non-electric energy consumption values are then added together to determine the building's weather normalized annual energy consumption. The total weather normalization adjustment is limited to a maximum adjustment of +/- 15%.*

The next step is to take the user's building and operating characteristics and apply those to the regression model for the type of building specified by the user for the benchmark and obtain a Predicted Source Energy use. The Mean Source Energy use from the regression model, a value from the multiple regression fit, is used with the Predicted Source Energy to form an Adjustment Factor. The Mean Source Energy is simply the mean value of the source energy records in the normalized curve:

Adjustment Factor = Predicted Source Energy / Mean Source Energy

The Fitted Source Energy Thresholds are then multiplied by the Adjustment Factor to obtain the Customized Source Energy Threshold use for each of the 100 threshold values:

Customized Source Energy Threshold_i = Fitted Source Energy Threshold_i x Adjustment Factor

The Weather Normalized Use, the actual consumption normalized for typical weather, is then compared to each of the Customized Source Energy Threshold values (1% to 100%). The lowest Customized Source Energy Threshold that is smaller than the Weather Normalized Use is the Energy Performance Rating of the building. Remember, this is on a scale of 1 to 100 and corresponds roughly to the percent of buildings with lower performance than the rated building.

For some building types, secondary spaces are allowed:

- Computer Data Centers
- Garages and Parking Lots
- Swimming Pools

The energy consumed in these secondary spaces is unlikely to be separately metered and requires an adjustment in the rating process. The derivation for the adjustments is described in EPA 1999. The values are added during the process. The values are based on the type of secondary space and the floor area and operating hours of the secondary space. For computer data centers, a constant of 359.5 kBtu/sqft-yr is used without an operating hour adjustment. For parking facilities a lighting and ventilation value is multiplied by the number of operating hours per year to arrive with an allowance. Adjustment for a swimming pool is also made. No additional adjustments are made for secondary spaces in buildings.

While the algorithm is not publicly available, it should be reproducible based on the data and description of the algorithm shown in the papers.

The user that enters data to determine their ENERGY STAR rating bases that data on information from utility bills and characteristics of the building. The utility bills, usually based on actual metered readings, are likely to be quite accurate. The heating and cooling degree-days are fairly accurate since they are based on zip code and the nearest weather station is likely to have very similar climatic conditions. The remaining building characteristics may be approximations. The number of computers, refrigerators, beds, etc., may be based on a quick informal count of those items or based on a reasonable approximation. Either way, they are unlikely to be incorrect by more than a few percent. The number of people is bound to vary and may be based on the number of people that should occupy the building instead of the actual average number of people in the building. The percent of the area that is heated and cooled is likely to be a low quality number since estimating floor areas is time consuming and an estimate would probably be considered sufficient for most users of the rating protocol. Fortunately, all of these factors each contribute little in the building energy use statistical model. For every building type, the floor area was the most important factor in the model. The quality of the floor area number entered by the user probably swamps the variation of the other values entered. So how good is the floor area number? According to the Professional Engineer's Guide:

> *The user-entered value for area must be the gross interior area of the building, or in the case of a user-specified office block, the gross interior area of the office block. This includes all area enclosed by the exterior walls of the building, including hallways, lobbies, stairways, elevator shafts, and electric/mechanical/janitorial closets. (EPA 2003b)*

While the definition of gross floor area is clear, it is unlikely to be known with great precision. Building occupants seldom have easy access to the as-built drawings of a building and, if they did, they would be unlikely to compute the gross floor area. Instead, owner occupants are likely to depend on the original specification for the building such as a rounded number like "50,000 square feet." Buildings with tenants are likely to know exactly the space that is rented out to each tenant, that number is part of a lease and is likely to be accurate, but it will probably not include common areas such as lobbies, closets and elevators. The professional engineer that certifies the area used as part of obtaining a label, is unlikely to recomputed the area based on drawings either. They will make sure that the area used is close based on some overall building dimensions. The exact definition used for floor area also varies depending on the reference. The definition that appears in ASHRAE Standard 90.1 is based the area enclosed by the exterior faces of the exterior walls. In addition, the data source for the statistical comparison, CBECS, EPRI, or HRG is likely to also be depending on just as approximate values for the data records in their respective databases.

4.2.5 Validation

Comparisons have been made between ENERGY STAR for Buildings and CBECS data and BOMA data in three papers written by people at the EPA (Hicks 2000a, Von Neida 2001, and Hicks 2004).

4.2.6 Weight of Energy

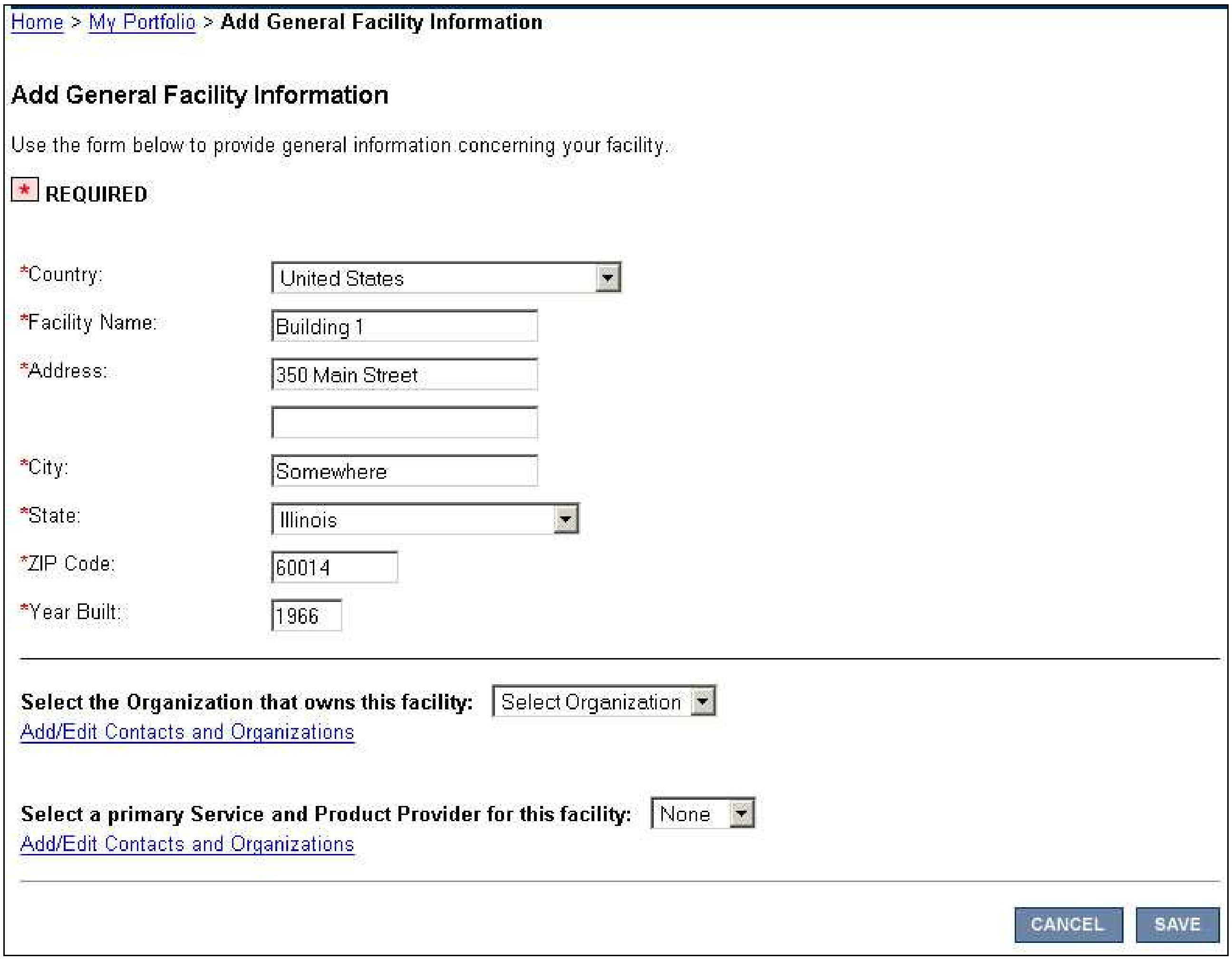
The ENERGY STAR Label for Buildings is not based on points and is entirely based on source energy consumption.

4.3 Application

The primary building cases, the input sensitivity cases with the primary buildings, and the supplemental buildings resulted in 472 evaluations using the ENERGY STAR for Buildings rating method also called Portfolio Manager. The rating tool is available on the http://www.energystar.gov/ web site. The input system for ENERGY STAR is the most sophisticated among the web-based rating methods. Individual building spaces are defined, each with parameters that depend on the type of space. Utility energy consumption is entered on a monthly basis. The user can enter a long-term history of the energy consumption for the facility. It was clearly designed not just for the one time rating but also for long-term use where the same facility would be rated periodically. Many facilities can also be entered and managed within the web site. The next few figures show the inputs.

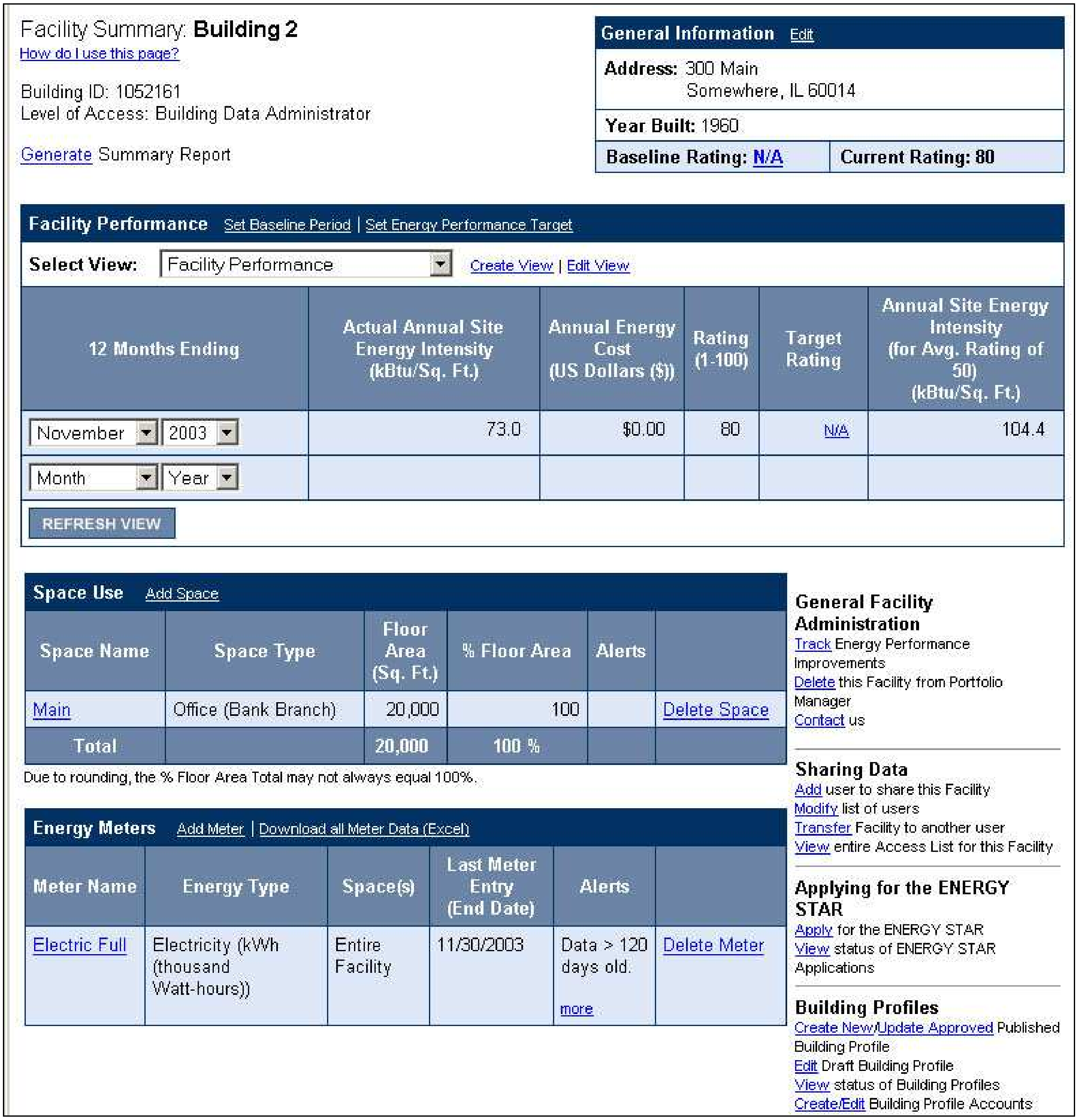
When adding a new facility to the ENERGY STAR Portfolio Manager the first page that comes up is shown in Figure 1.

Figure 1– Add Facility Page for ENERGY STAR



After the new facility is added a page similar to the one shown below is displayed. This shows the facility summary page that shows the current rating for the building and lists the space names and meter names. If the building were just being rated for the first time, the user would need to add spaces and meters. This page also shows the rating of the facility as shown on Figure 2.

Figure 2 – Facility Summary Page for ENERGY STAR



Facility Summary: **Building 2**
How do I use this page?

Building ID: 1052161
Level of Access: Building Data Administrator

Generate Summary Report

General Information Edit	
Address: 300 Main Somewhere, IL 60014	
Year Built: 1960	
Baseline Rating: N/A	**Current Rating: 80**

Facility Performance Set Baseline Period | Set Energy Performance Target

Select View: Facility Performance — Create View | Edit View

12 Months Ending	Actual Annual Site Energy Intensity (kBtu/Sq. Ft.)	Annual Energy Cost (US Dollars ($))	Rating (1-100)	Target Rating	Annual Site Energy Intensity (for Avg. Rating of 50) (kBtu/Sq. Ft.)
November 2003	73.0	$0.00	80	N/A	104.4
Month Year					

REFRESH VIEW

Space Use Add Space

Space Name	Space Type	Floor Area (Sq. Ft.)	% Floor Area	Alerts	
Main	Office (Bank Branch)	20,000	100		Delete Space
Total		20,000	100 %		

Due to rounding, the % Floor Area Total may not always equal 100%.

Energy Meters Add Meter | Download all Meter Data (Excel)

Meter Name	Energy Type	Space(s)	Last Meter Entry (End Date)	Alerts	
Electric Full	Electricity (kWh (thousand Watt-hours))	Entire Facility	11/30/2003	Data > 120 days old. more	Delete Meter

General Facility Administration
Track Energy Performance Improvements
Delete this Facility from Portfolio Manager
Contact us

Sharing Data
Add user to share this Facility
Modify list of users
Transfer Facility to another user
View entire Access List for this Facility

Applying for the ENERGY STAR
Apply for the ENERGY STAR
View status of ENERGY STAR Applications

Building Profiles
Create New/Update Approved Published Building Profile
Edit Draft Building Profile
View status of Building Profiles
Create/Edit Building Profile Accounts

Clicking on the "Add Space" link brings up a page asking for the name of the space and lets the user choose between several different primary and secondary space types. The primary space types, one that must occur in each building, are:

- Hospital (Acute Care, Children's)
- Hotel/Motel
- K-12 School
- Medical Office
- Office
- Residence Hall/Dormitory
- Supermarket/Grocery
- Warehouse and Storage

The secondary spaces include:

- Ambulatory Surgical Center
- Computer Data Center
- Garage/Parking
- Other
- Swimming Pool

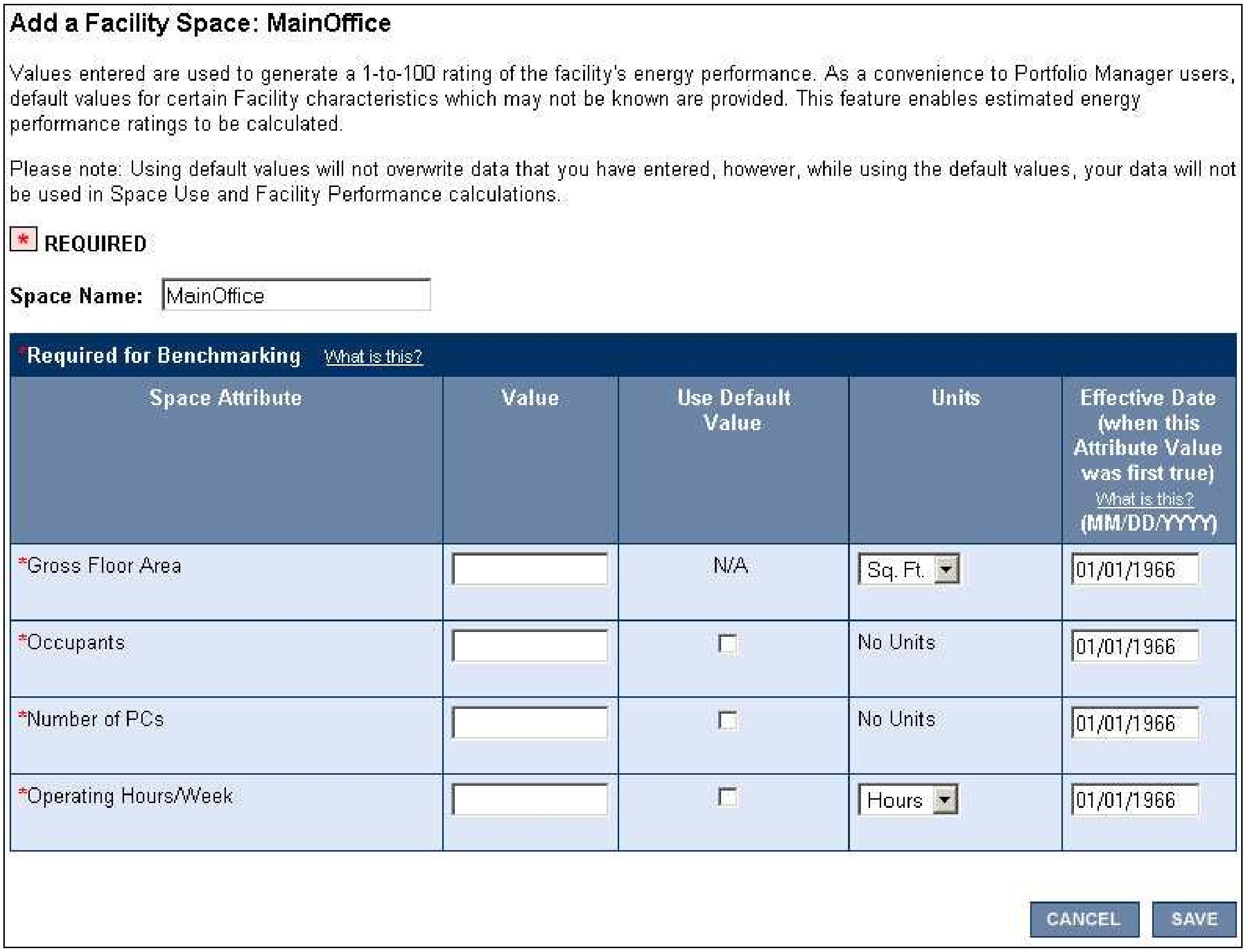
The user can also enter an Effective Date which is "used by Portfolio Manager to determine the starting date for including this Space's attributes in the overall calculation of the facility's energy performance rating." Thus, revision tracking of changing parameters about a building is supported.

Depending on the space type chosen an additional page may ask for a sub type of space. For example, office buildings provide the choice of:

- General
- Branch Bank
- Courthouse
- Financial Center

Choosing “General” brings up the page shown below in Figure 3.

Figure 3 – Add A Space Page for ENERGY STAR



Add a Facility Space: MainOffice

Values entered are used to generate a 1-to-100 rating of the facility's energy performance. As a convenience to Portfolio Manager users, default values for certain Facility characteristics which may not be known are provided. This feature enables estimated energy performance ratings to be calculated.

Please note: Using default values will not overwrite data that you have entered, however, while using the default values, your data will not be used in Space Use and Facility Performance calculations.

* REQUIRED

Space Name: MainOffice

***Required for Benchmarking** What is this?

Space Attribute	Value	Use Default Value	Units	Effective Date (when this Attribute Value was first true) What is this? (MM/DD/YYYY)
*Gross Floor Area		N/A	Sq. Ft.	01/01/1966
*Occupants			No Units	01/01/1966
*Number of PCs			No Units	01/01/1966
*Operating Hours/Week			Hours	01/01/1966

CANCEL SAVE

On the facility summary screen, clicking on a space name on the facility summary screen brings up the space details page that allows any entry to be edited. The parameters shown depend on the space type chosen as shown in Figure 4 below.

Figure 4 – Space Details Page for ENERGY STAR

Home > My Portfolio > Building 2 > **Edit Facility Space**

Edit Facility Space: Main

Entered values are used when generating a **1-to-100 rating** of the facility's energy efficiency. Portfolio Manager provides default values for certain Space attributes. Using default values will not overwrite data that you have entered, however, while using the default values, your data will not be used in Space Use and Facility Performance calculations.

* REQUIRED

*Space Name: Main CANCEL SAVE

Current Space Attribute Values What is this?

Space Attribute	Value	Use Default Value	Units	Effective Date (when this Attribute Value was first true) What is this? (MM/DD/YYYY)	Last Updated By	
Gross Floor Area (required for benchmarking)	20000.00	N/A	Sq. Ft.	12/01/2001	JASONGLAZER	Edit
Occupants (required for benchmarking)	60.00			12/01/2002	JASONGLAZER	Edit
Number of PCs (required for benchmarking)	45.00			12/01/2001	JASONGLAZER	Edit
Operating Hours/Week (required for benchmarking)	80.00		Hours	12/01/2001	JASONGLAZER	Edit

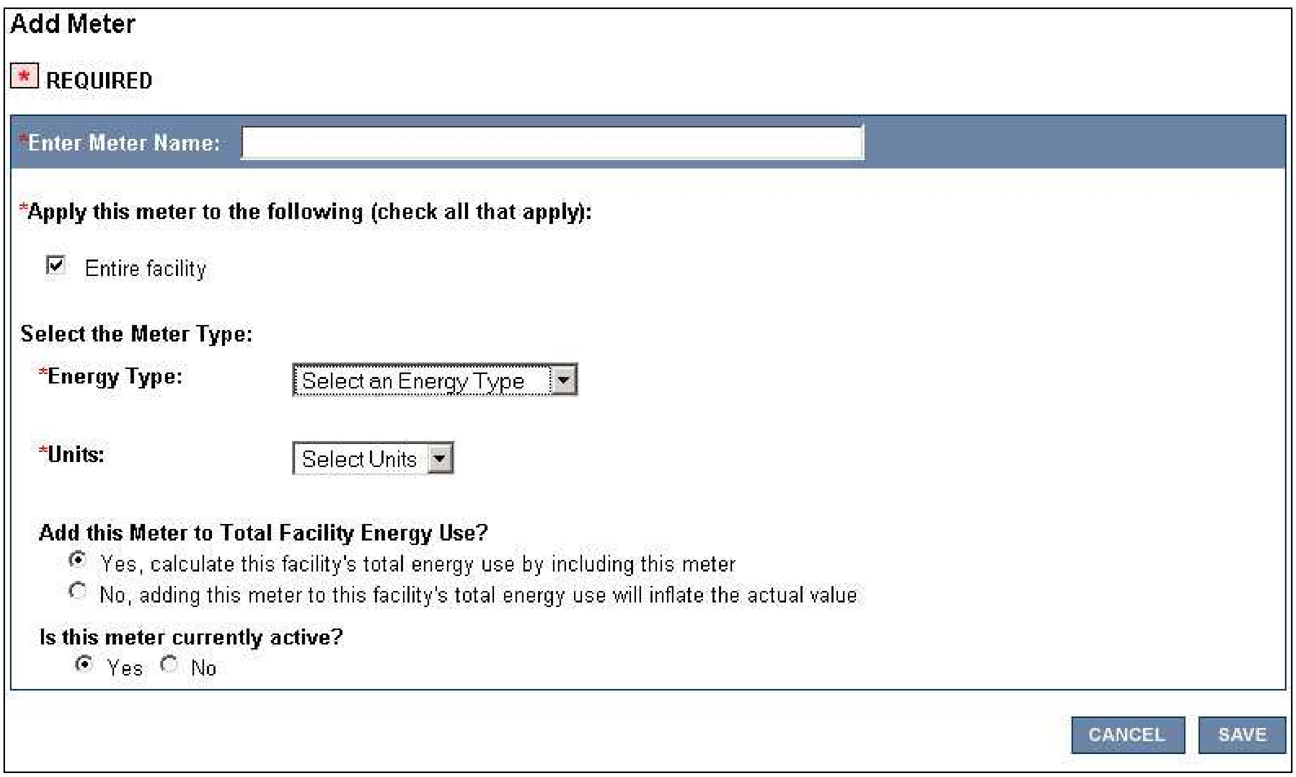
Space Revision History

Space Attribute	Value	Use Default Value	Units	Effective Date (when this Attribute Value was first true) What is this? (MM/DD/YYYY)	Revised by	
Occupants (required for benchmarking)	50.00			12/01/2001	Jason Glazer	Edit

Adding a new meter brings up the following figure, Figure 5. The options for energy type are:

- Electricity
- Natural Gas
- Fuel Oil (No. 2)
- Steam
- Chilled Water
- Wood
- Propane
- Liquid Propane
- Other
- Kerosene
- Fuel Oil (No. 1)
- Fuel Oil (No. 4)
- Fuel Oil (No. 5 and No. 6)
- Diesel (No. 2)
- Coal (anthracite)
- Coal (bituminous)
- Coke

Figure 5 – Add a Meter Page for ENERGY STAR



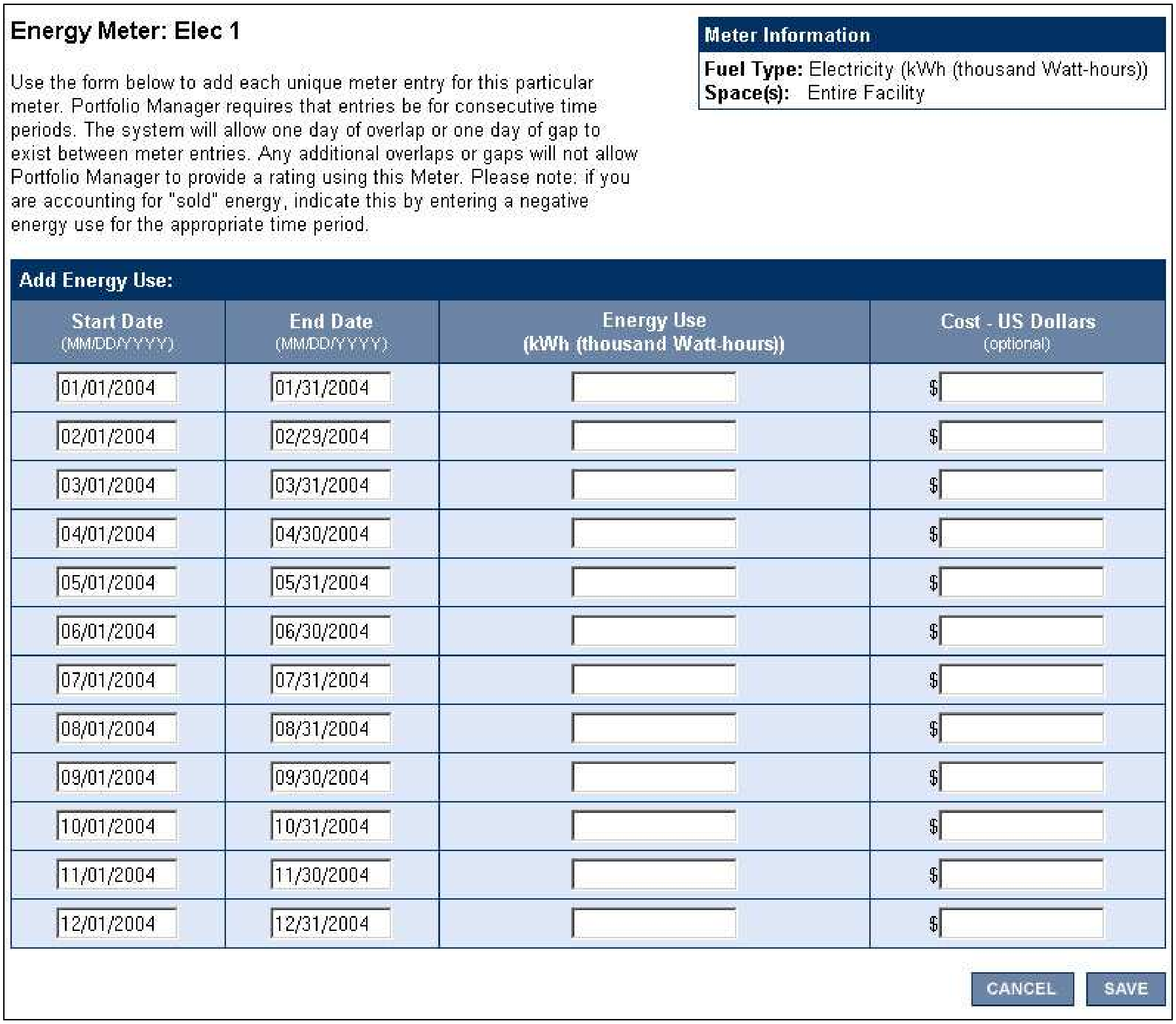
Depending on the fuel chosen, the units displayed include some of the following:

- ccf (hundred cubic feet)
- cf (cubic feet)
- daily tons
- gallons

- kBtu (thousand Btu)
- kcf (thousand cubic feet)
- KLbs. (thousand pounds)
- kWh (thousand Watt-hours)
- MBtu (million Btu)
- MCF(million cubic feet)
- MLbs. (million pounds)
- MWh (million Watt-hours)
- pounds
- therms
- ton hours
- tons

After that, a web page asking for the number of months of billing data that are to be entered and what the start date of the first billing period is displayed. Following this, a web page appears that allows the entry of the monthly energy consumption and energy cost for that meter, as shown below in Figure 6.

Figure 6 – Edit Meter Page for ENERGY STAR



Energy Meter: Elec 1

Use the form below to add each unique meter entry for this particular meter. Portfolio Manager requires that entries be for consecutive time periods. The system will allow one day of overlap or one day of gap to exist between meter entries. Any additional overlaps or gaps will not allow Portfolio Manager to provide a rating using this Meter. Please note: if you are accounting for "sold" energy, indicate this by entering a negative energy use for the appropriate time period.

Meter Information

Fuel Type: Electricity (kWh (thousand Watt-hours))
Space(s): Entire Facility

Add Energy Use:

Start Date (MM/DD/YYYY)	End Date (MM/DD/YYYY)	Energy Use (kWh (thousand Watt-hours))	Cost - US Dollars (optional)
01/01/2004	01/31/2004		$
02/01/2004	02/29/2004		$
03/01/2004	03/31/2004		$
04/01/2004	04/30/2004		$
05/01/2004	05/31/2004		$
06/01/2004	06/30/2004		$
07/01/2004	07/31/2004		$
08/01/2004	08/31/2004		$
09/01/2004	09/30/2004		$
10/01/2004	10/31/2004		$
11/01/2004	11/30/2004		$
12/01/2004	12/31/2004		$

CANCEL SAVE

The primary result of the rating process is shown on the facility summary page, as is a simple number from 0 to 100 labeled as the “current rating.” Additional results can be displayed on the Facility Summary page depending on view selected such as the capability to view any combination of variables. The list of output variables is shown below in Table 26.

Table 26 – Output Variables for ENERGY STAR

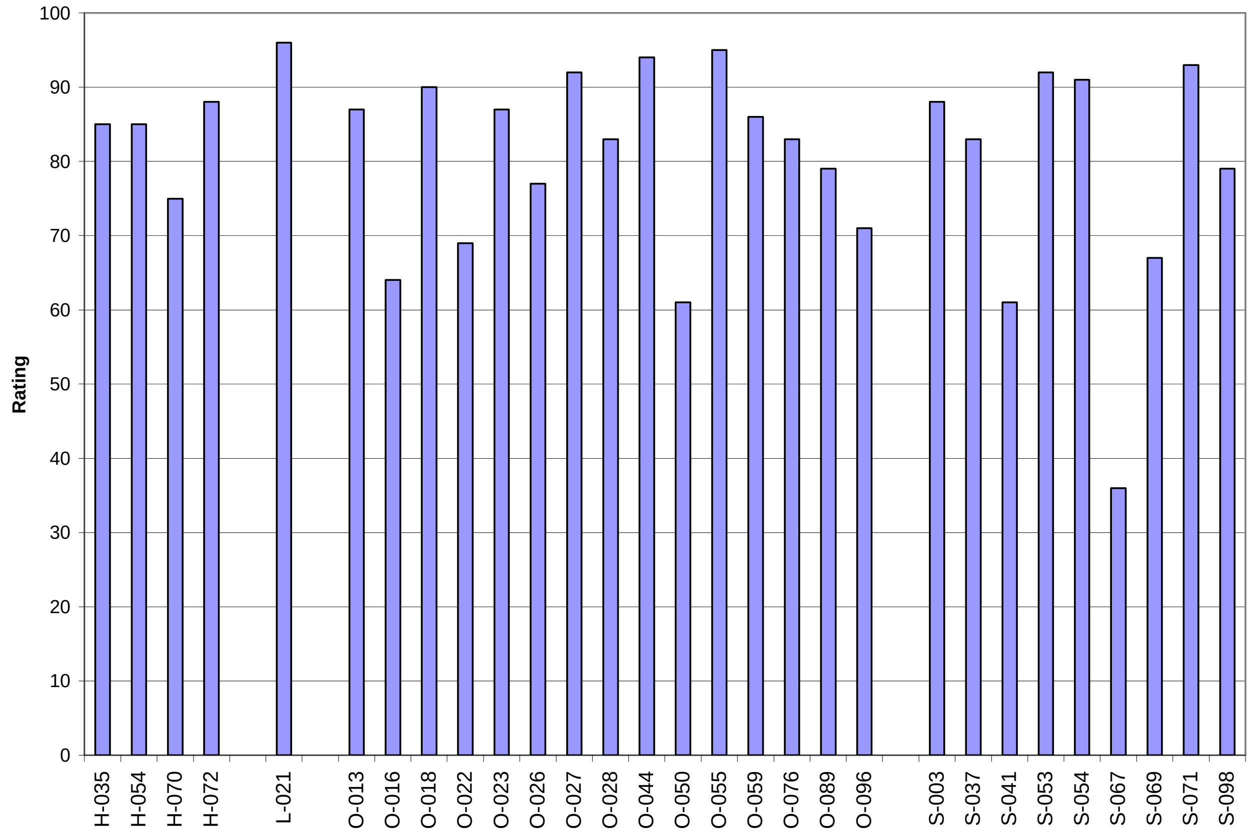
Variable	*Type*	*Units*
Rating		
Benchmark Results		
Target Rating	Benchmark Results	
Baseline Annual Site Energy Intensity	Comparative	kBtu/Sq. Ft.
Baseline Period	Comparative	
Baseline Rating	Comparative	
Current Annual Site Energy Intensity	Comparative	kBtu/Sq. Ft.
Current Period	Comparative	
Current Rating	Comparative	
Actual Annual Site Energy Intensity	Energy Use	kBtu/Sq. Ft.
Annual Site Energy Intensity (for Avg. Rating of 50)		
Energy Use		kBtu/Sq. Ft.
Energy Savings	Energy Use	kBtu (thousand Btu)
Energy Savings per Sq. Ft.	Energy Use	kBtu/Sq. Ft.
Energy Use Alerts	Energy Use	
Initial Weather Normalized Annual		
Source Energy Intensity	Energy Use	
Period Ending	Energy Use	kBtu/Sq. Ft.
Total Energy Use	Energy Use	kBtu (thousand Btu)
Weather Normalized Annual		
Source Energy Intensity	Energy Use	kBtu/Sq. Ft.
CO2 Reduced	Environmental	pounds
Annual Energy Cost	Financial	US Dollars ($)
Cumulative Investment	Financial	US Dollars ($)
Cumulative Investment per Sq. Ft.	Financial	US Dollars ($)
Total Energy Cost per Sq. Ft.	Financial	US Dollars ($)
Building Owner	Organizations	
Service and Product Provider	Organizations	
Zip Code	Organizations	
Building Type	Space Use	
Number of Occupants	Space Use	
Number of Students	Space Use	
Space Use Alerts	Space Use	
Total Floor Space	Space Use	Sq. Ft.
Building Profile Status	Status	
Eligibility for the ENERGY STAR	Status	
ENERGY STAR Application Status	Status	
Full Year	Status	
Last Modified	Status	

The variables shown in the table may appear in a built-in “view” or may be combined into custom views. Many of these variables would be used to confirm the inputs provided by the user.

4.4 Baseline

The result from using ENERGY STAR for Buildings is a value between 0 and 100. These rating results are shown in the following figure, Figure 7, for the four types of primary buildings shown throughout the report as a letter followed by a three digit number. The letter is 'H' for hospital, 'L' for lodging such as hotels and motels, 'O' for office buildings, and 'S' for school. The hospital ratings are clustered between 75 and 88 while the schools have a much broader set of ratings from 36 to 93. Office buildings have a range of ratings from 61 to 95.

Figure 7 – ENERGY STAR Baseline Ratings



4.5 Input Sensitivity

To gain some understanding of how the input parameters affect the ratings, a variety of permutations were evaluated with each of the 29 primary buildings. The permutations evaluate one input variable at a time and leave the remaining input variables at the baseline values. The permutations are described in the following table, Table 27.

Table 27 – ENERGY STAR Permutations

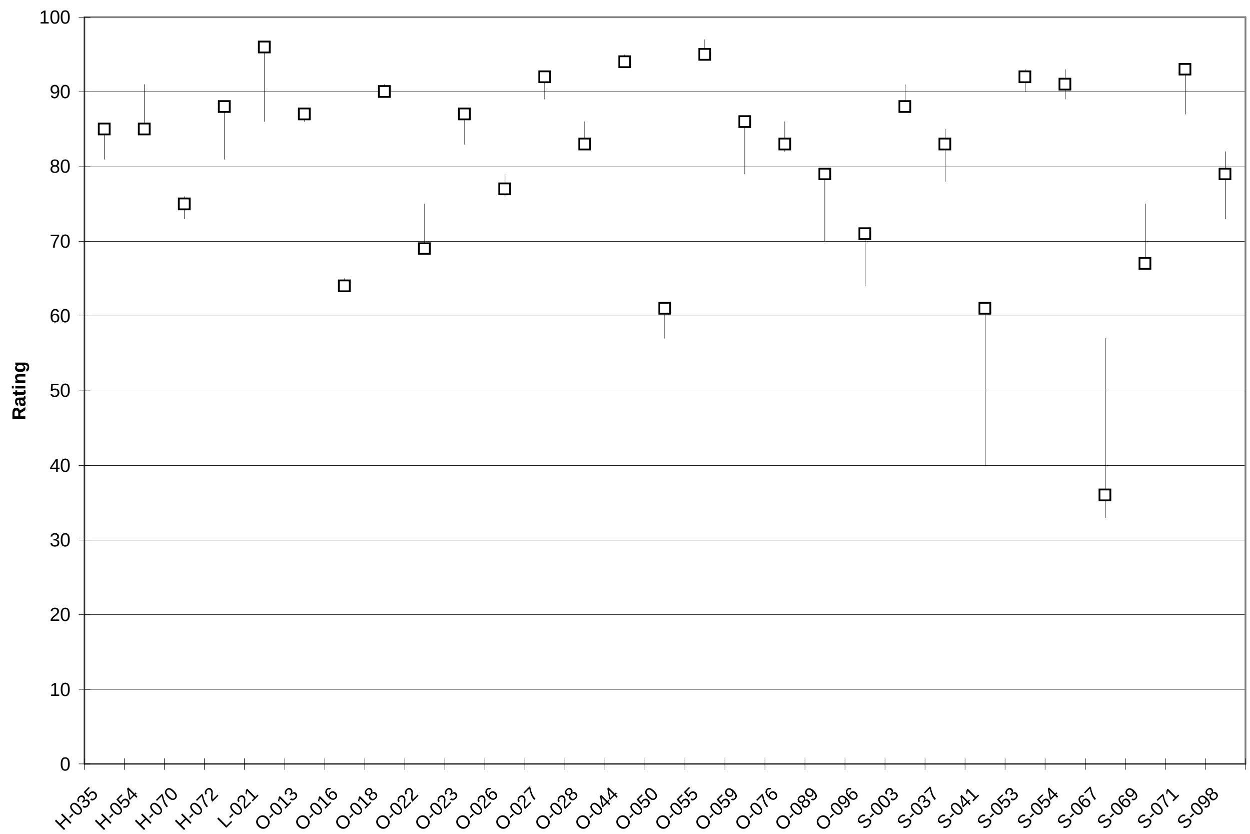
Permutation ID	*Buildings*	*Description*
COLDZIP	All	ZIP code for Portland Maine - New England - Census Div 1 - 04101
HOTZIP	All	ZIP code for Dallas Texas - West South Central - Census Div 7 – 75201
INVCOOK	School	Toggle the entry “Are there on-site Cooking Facilities?”
INVTER	Hospital	Toggle the entry “Are tertiary care services offered on-site?”
INVVENT	School	Toggle the entry “Is this building mechanically ventilated?”
M15AC	School	Reduce the “What percent of this space is air-conditioned?” by 15%
M15AREA	All	Reduce the building area by 15%
M15BED	Hospital	Reduce the “Number of Licensed Beds” by 15%
M15ENERGY	All	Each monthly meter consumption reduced by 15%
M15FLR	Hospital	Reduce the “Number of Licensed Beds” by 15%
M15HRS	Office/School	Reduce the “Operating Hours/Week” by 15%
M15HT	School	Reduce the “What percent of this space is heated?” by 15%
M15MON	School	Reduce the “How many months is this building in use?” by 15%
M15OCC	Office	Reduce the number of occupants by 15%
M15PC	Office/School	Reduce the “Number of PCs” by 15%
M15ROOM	Lodging	Reduce the “Number of Rooms” by 15%
M15STU	School	Reduce the “Number of Students” by 15%
P15ENERGY	All	Each monthly meter consumption increased by 15%

The location that a building is rated in is important since the same building would consume more cooling electricity in a warmer climate and more heating energy in a colder climate. Figure 8 shows the impact of taking the 29 baseline buildings and rating them in two different locations.

- Portland Maine 04101
- Dallas Texas 75201

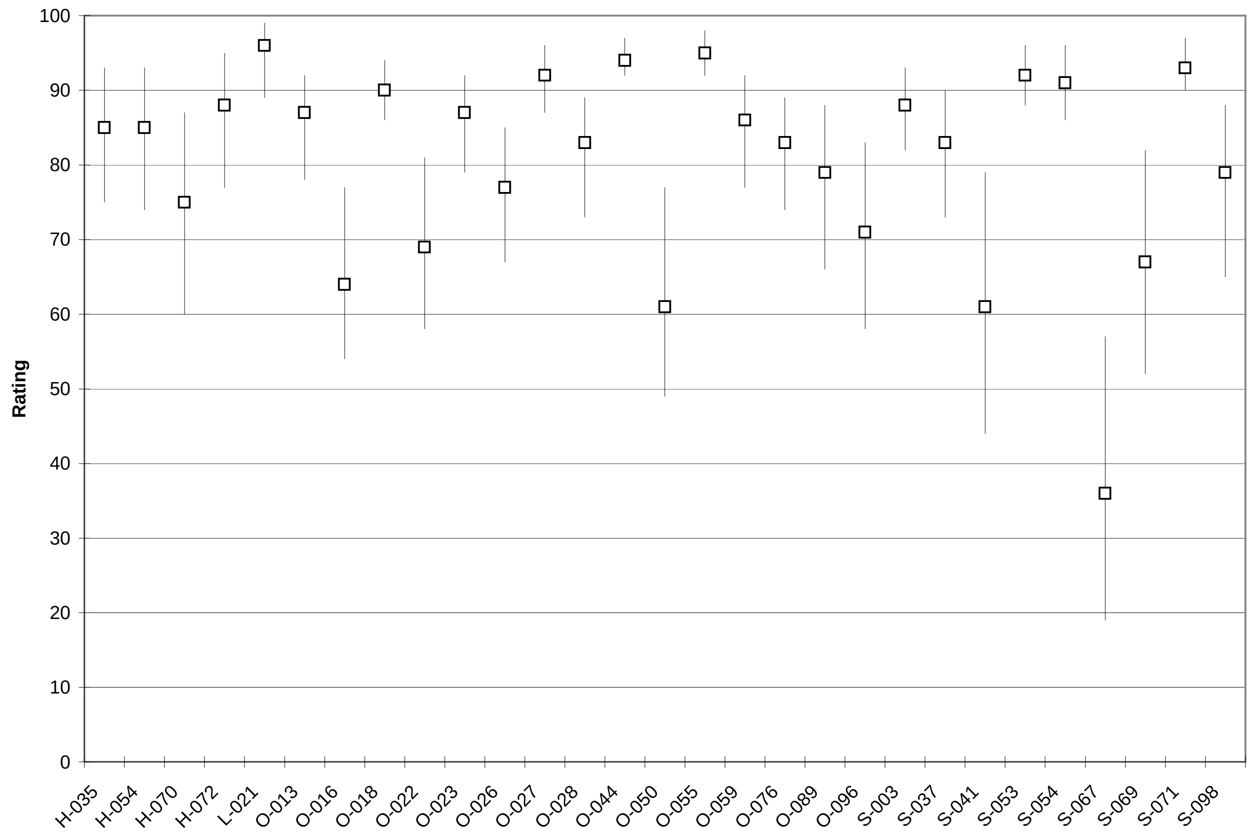
On the graph, the box represents the baseline rating while the top and bottom of the line represent the ratings at the two locations. Office buildings show almost no impact to more extreme hot or cold climates with an average range of 4%. Hospitals show only slightly more range than offices with an average range of 5%. Schools show some of the largest impacts based on changing the climate with two buildings having more than a 20% range while the group averages 9% change based on climates.

Figure 8 – ENERGY STAR Ratings for Hot and Cold Climates



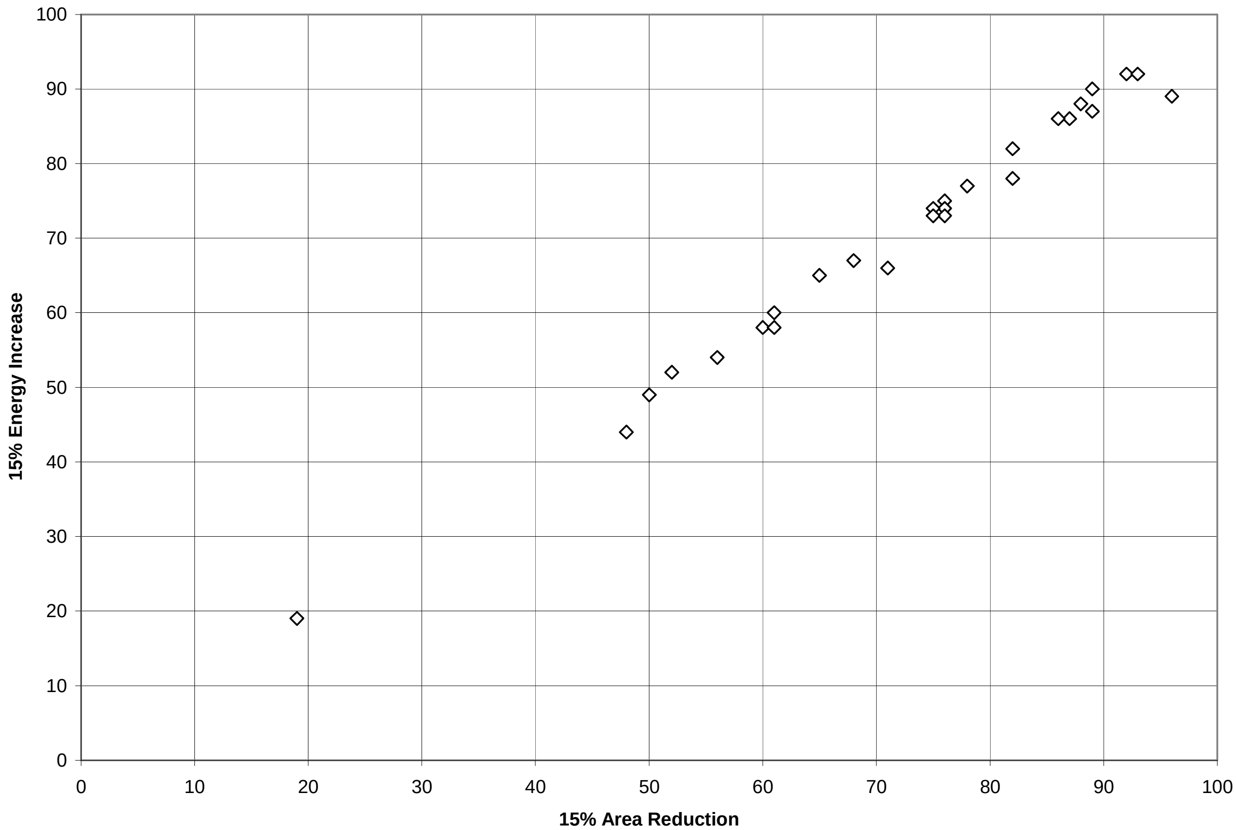
Repeating the rating process using ENERGY STAR but with 15% less monthly energy consumption or 15% more monthly energy consumption results in a range of ratings for each building as shown in Figure 9. On the graph, the box represents the baseline rating while the top and bottom of the line represent the ratings at the 15% less and 15% more energy consumption. The 15% change for area and utility energy consumption was chosen to provide adequate differentiation between cases but not to push the building beyond a reasonable range. The impact of increasing or decreasing the energy consumption is nearly symmetric with increases and decreases being similar for each individual building. In addition, the impact of increasing and decreasing the energy consumption 15% seems to be greatest for buildings that have the lowest rating and smaller for buildings with better ratings. The impact between building types does not appear to be significant.

Figure 9 – ENERGY STAR Rating with Plus and Minus 15% Energy Consumption



The impact of changing the floor area and the energy consumption was also investigated. The energy intensity when reducing the area by 15% is very close to the energy intensity when increasing the energy by 15% (ratios of 1/0.850 = 1.176 versus 1.150). Figure 10 shows the ENERGY STAR rating of the same building using reduced area and increased energy. The regression model based on this data has a slope of nearly unity (0.99) and the fit of the model is very good with an R^2 of 0.99. The high degree of fit implies that while the ENERGY STAR rating is directly affected by both energy use and area, it is the ratio of energy to area, the energy intensity, which most fully captures that effect.

Figure 10 – Comparative Ratings of Reduced Area and Increased Energy with ENERGY STAR



The entry pages in ENERGY STAR for a hospital have several input fields that are not present in other buildings. Reducing the number of beds by 15% resulted in a 0 to 1% drop in the rating. Likewise, reducing the maximum number of floors in the hospital input by 15% resulted in a 1 to 2% drop in the rating. The input field “Are tertiary care services offered on-site?” can be either yes or no. The impact of going from the yes to the no value was 6 to 7% for the four hospitals evaluated.

For the one lodging building evaluated in the primary building set, the impact of reducing the “Number of Rooms” by 15% was a decrease of the rating from 96 to 87.

Two of the inputs for schools had minimal impacts. A reduction in “What percent of this space is air-conditioned” by 15% reduced the rating 0 to 3% with an average of a 1% reduction. Similarly, a reduction in the “Number of Students” by 15% also reduced the rating of the schools by 0 to 3% with an average of just over 1%.

Figure 11 shows the impact on the ratings of schools for a 15% reduction in heated area. The rating is consistently lower. The amount of impact is larger for buildings with lower ratings and ranges from 2 to 8%.

Figure 11 – ENERGY STAR Rating for Schools with Reduced Heated Area

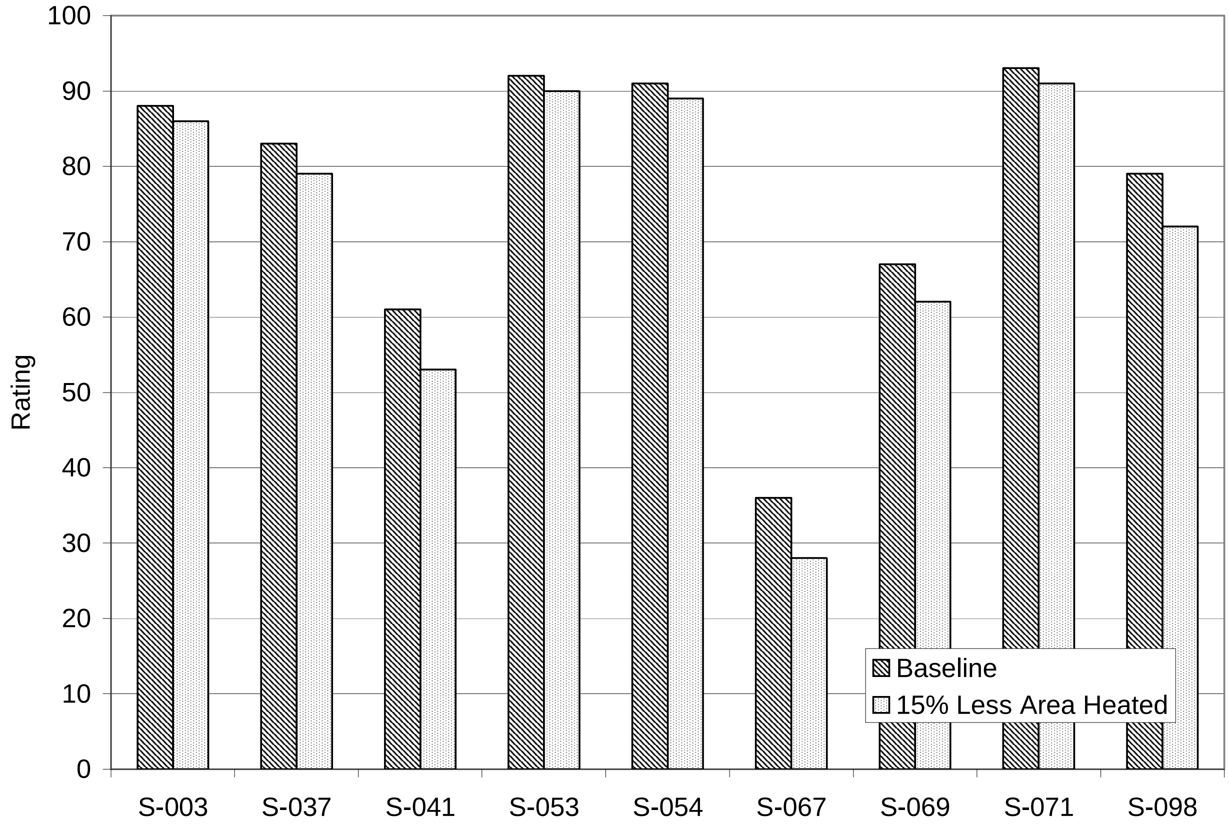
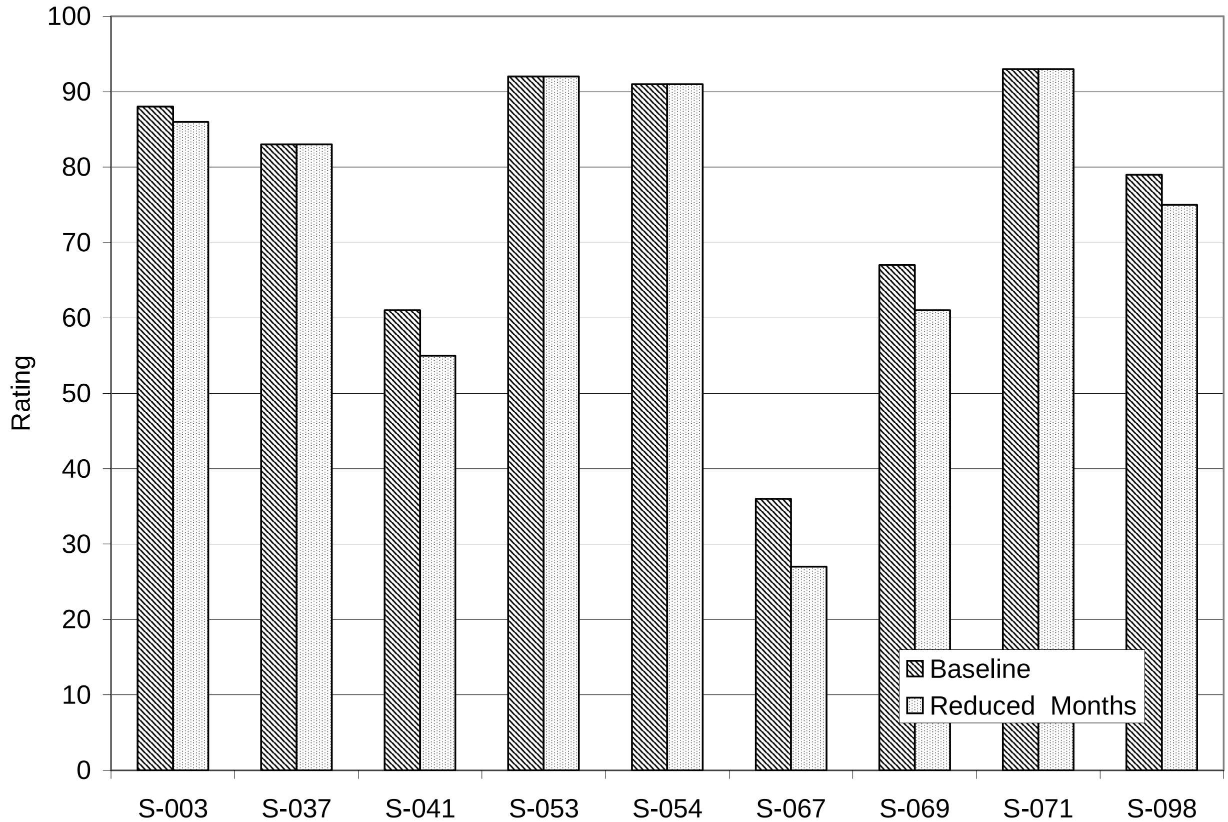


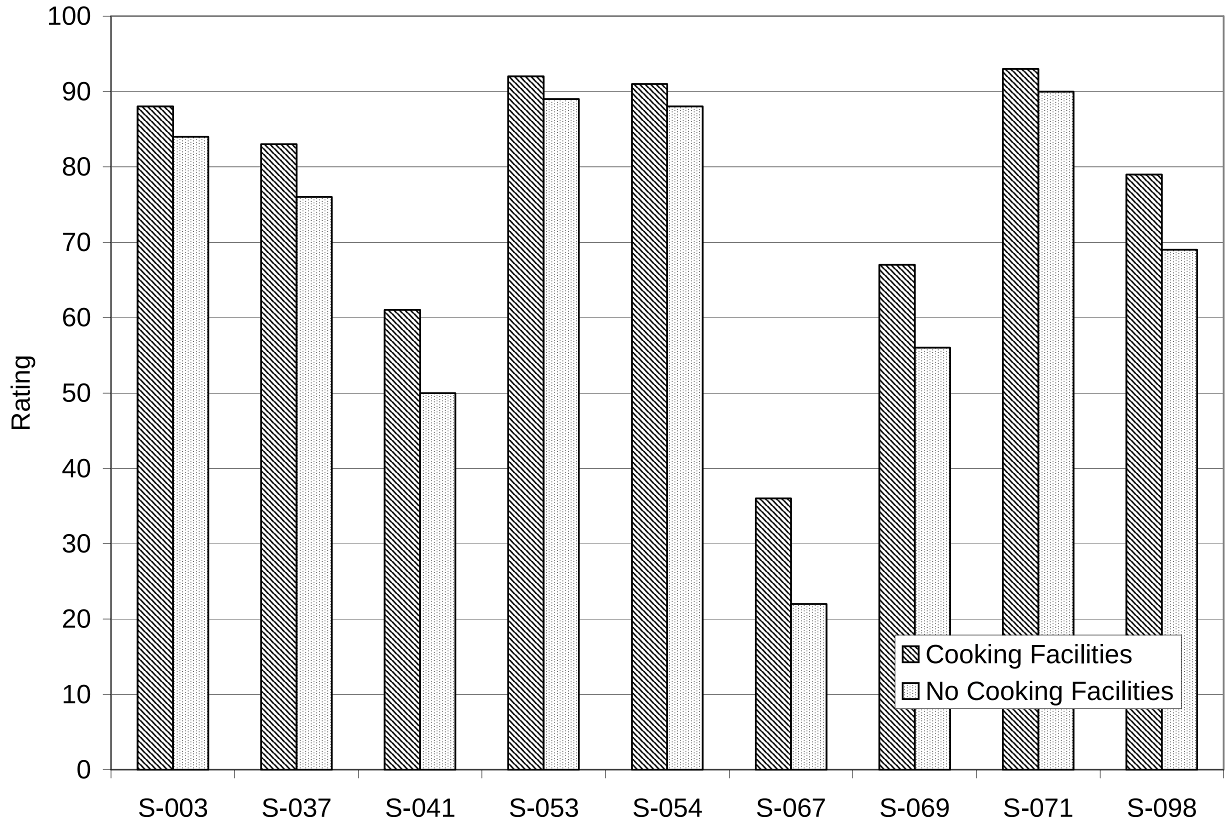
Figure 12 below shows the impact of reducing the number of operating months for schools. While many schools operate a traditional shortened year, five of the nine schools evaluated operate a full year. These five schools had 12 months of operation and were reduced to 10 months, which resulted in a reduction in their rating of 2 to 9%. The four schools that specified they operate 10 months per year normally when reduced to 9 months had no impact to their ratings. This could be due to either a lower limit on the number of months that causes a change to the rating or to an absolute lower limit on the number of months input that affects the rating.

Figure 12 – ENERGY STAR Rating for Schools with Reduced Months of Operation



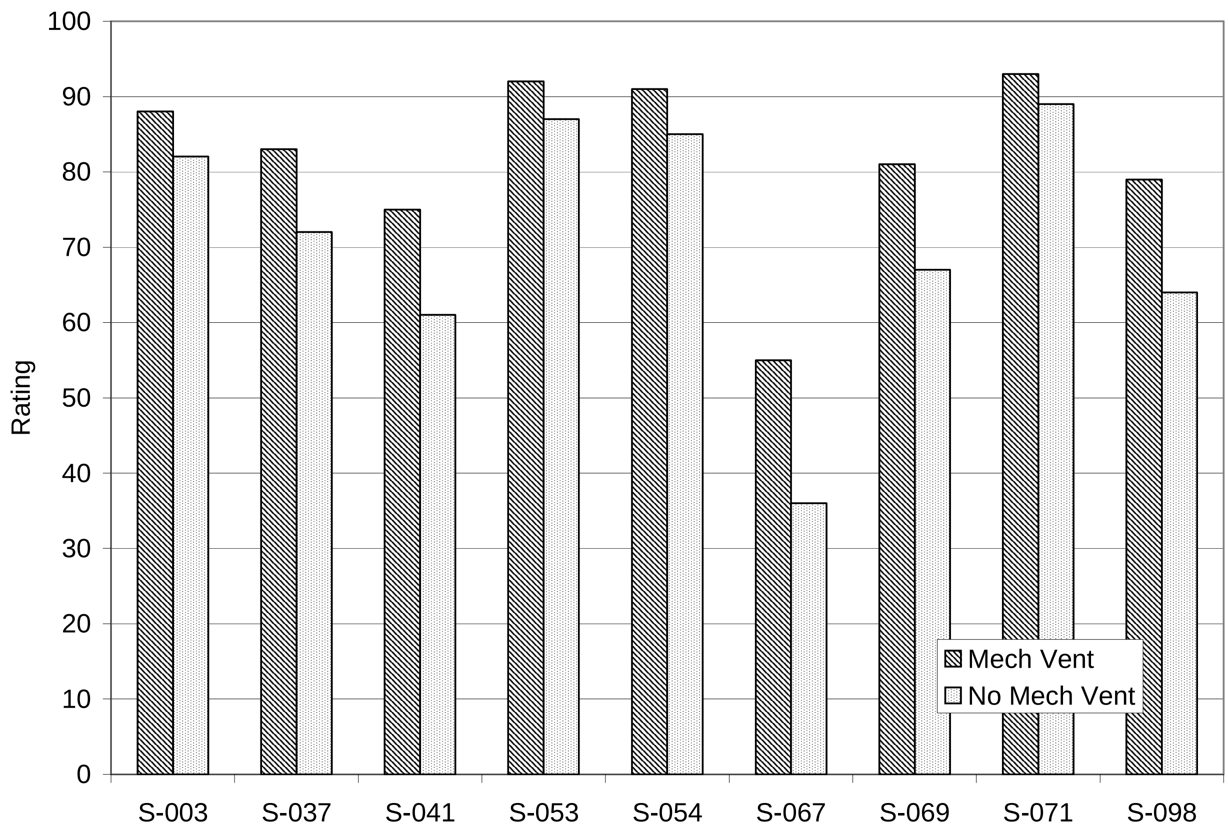
All the schools had on-site cooking facilities and when the rating was recomputed stating that no on-site cooking facilities were included, the ratings were reduced by 3 to 14% with an average reduction of 7% as shown below in Figure 13. This is a very significant impact for the presence of cooking facilities in the school. For schools, one of the largest single loads in the building may be in the kitchen. For the lowest rated building, S-067, the impact of 14% seems exaggerated and makes the cooking consumption seem one of the only drivers for the baseline rating.

Figure 13 – Cooking Impacts for ENERGY STAR Rating in Schools



For the nine schools evaluated, six had mechanical ventilation in the building and three did not. The ratings were run again for the nine schools changing the response to the question "Is this building mechanically ventilated " from yes to no and from no to yes. Figure 14 presents the results of these permutations. Generally, ratings were lower when no mechanical ventilation is provided. The impact was a reduction in rating of 6 to 19% with an average of 10% for buildings without mechanical ventilation. This essentially acts as a credit to provide mechanical ventilation in a building. Many older schools and some newer schools rely on operable windows for ventilation. Some buildings designed to be "green" buildings rely on natural ventilation and do not have any central fan system and these buildings would be rated more poorly than a similar building with a forced air ventilation system.

Figure 14 – ENERGY STAR Ratings for Schools with Mechanical Ventilation



Both office buildings and schools include input fields for "Operating Hours/Week" and the "Number of PCs". Both of these inputs were rated with the value entered reduced by 15%. For both of these changes the impacts were small ranging from 0 to 2% for Number of PCs and from 0 to 3% for Operating Hours/Week. The average of both was a reduction in the rating by approximately 1%. The fact that these two inputs both had similar impacts on the rating seems unintuitive since the length of operation for a building is normally associated directly with energy consumption. Perhaps the impact to this is purposely minimized to reduce gaming by people seeking a rating to claim different operating hours since those are difficult to confirm.

For office buildings, the user can enter the number of occupants. The office buildings were rated again with a 15% reduction in this parameter. Like operating hours and number of PCs, this input seemed to have minimal impact with small changes of 0 to 3% and an average change of 1.5%. The change is largest for the lower rated buildings and smallest for the higher rated buildings.

4.6 Supplementary Buildings

The 167 supplementary buildings taken from the North West Energy Efficiency Alliance's Commercial Building Stock Assessment were rated using ENERGY STAR for Buildings. This allowed understanding trends in the data that would not be apparent in the smaller primary data set of 29 buildings. Of the 167 buildings rated, 29 did not qualify for a rating. Of the 29 that did not qualify for a rating, one was a hospital, two were schools, 15 were office buildings and 11 were lodging. A very large fraction of the lodging buildings did not qualify, eleven out of sixteen, and the primary reason provided by the ENERGY STAR for Building website was that the number of rooms, presumably guest rooms, was much higher or lower than normal. This restriction on the number of rooms or the number of rooms per area may be too narrow since such a large fraction of lodging buildings did not qualify.

For schools, the energy intensity and the rating are displayed together on Figure 15. In general, higher ratings occur with lower energy intensities. When applying a regression model to the data, the resulting linear equation has a R^2 of 0.85.

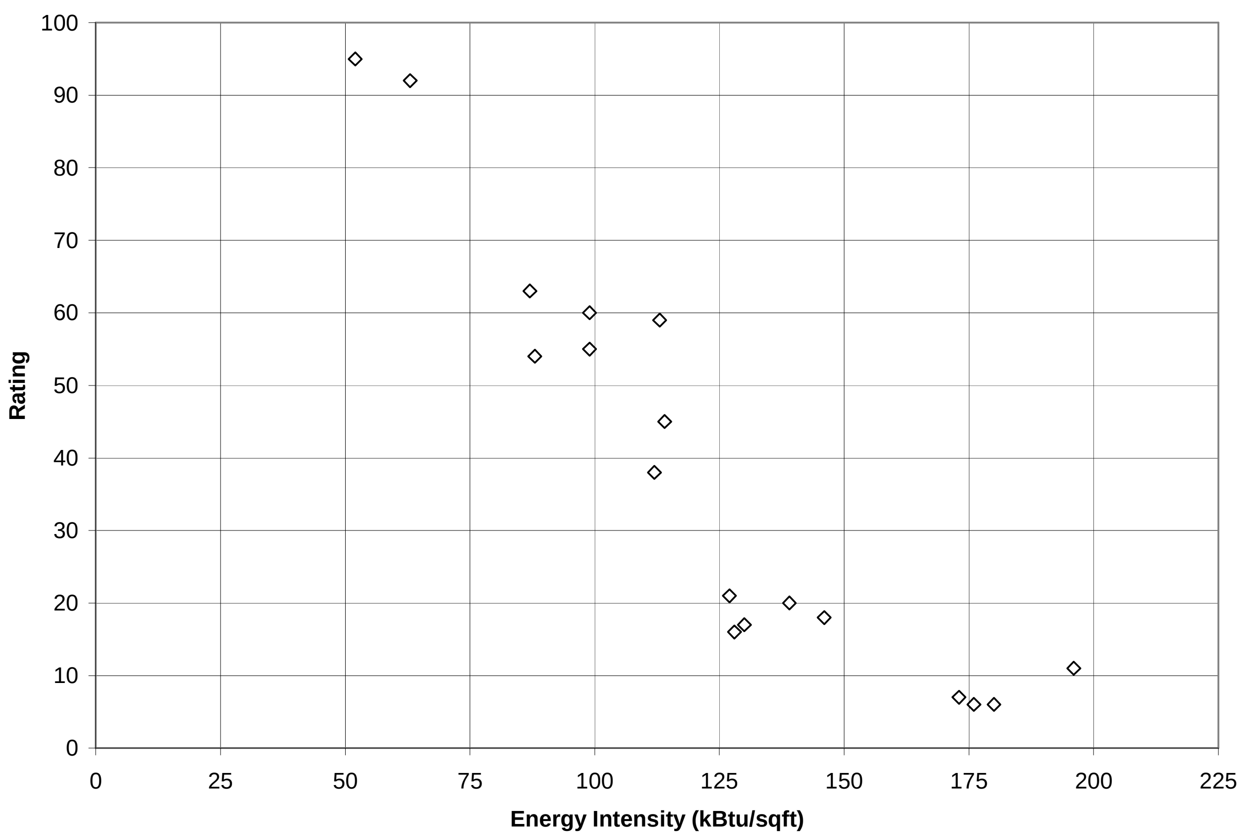
$$y = -0.6601x + 119.43$$

The Y-intercept can represent the rating for a net-zero energy building. Of course in ENERGY STAR the range of the rating is 0 to 100 so a value of 119 is impossible to receive. A quadratic fit to the data provides a higher R^2 of 0.93 and matches the general shape of the distribution.

$$y = 0.0044x^2 - 1.7633x + 182.18$$

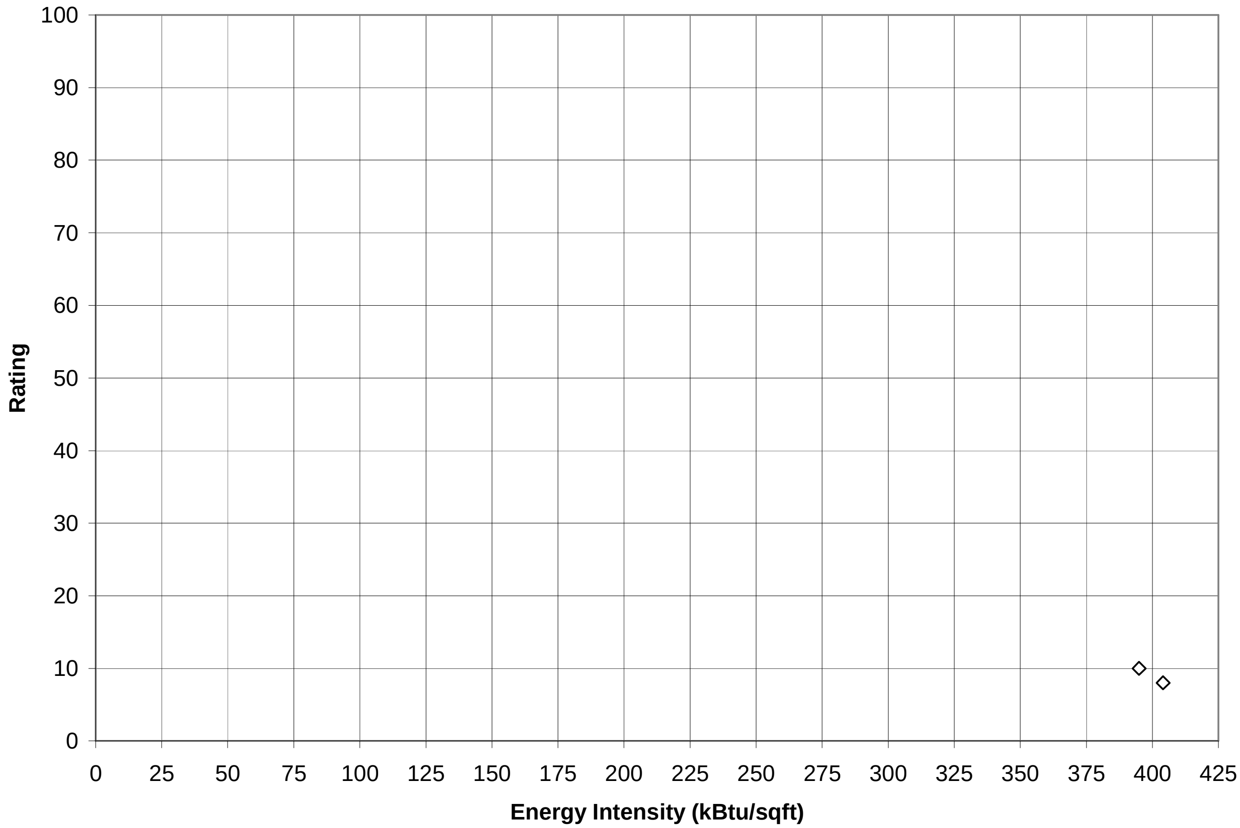
The spread of the data is based on the influence of parameters besides energy intensity such as climate, etc.

Figure 15 –Supplementary Schools in ENERGY STAR



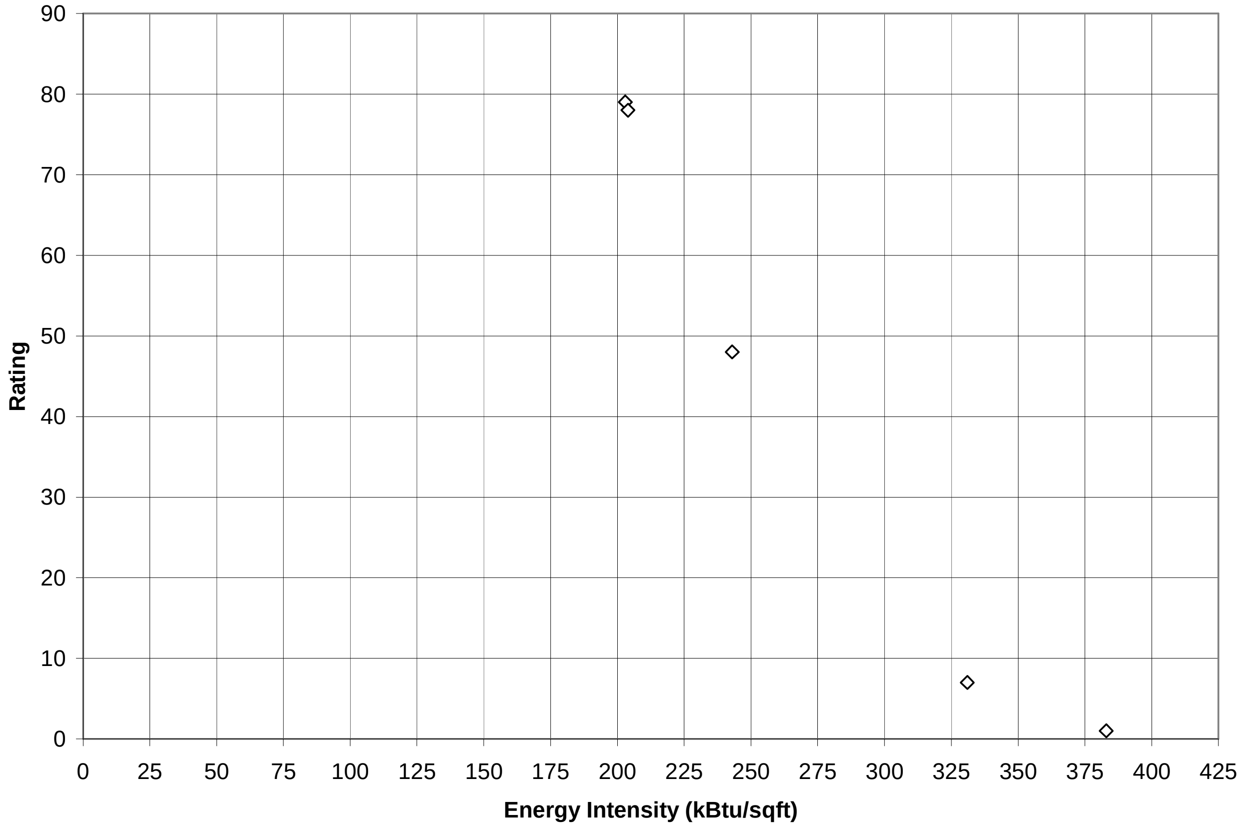
Only two hospitals from the supplemental database qualified and those are shown on, Figure 16. Few if any conclusions can be drawn based on these buildings but both are rated very poorly.

Figure 16 –Supplementary Hospitals in ENERGY STAR



As already discussed, 11 out of the 16 lodging buildings did not qualify for a rating. The five remaining buildings are shown on Figure 17. The points seem to fit very well to a curve but the few distinct points makes applying a regression model to this few points invalid.

Figure 17 –Supplementary Lodging in ENERGY STAR

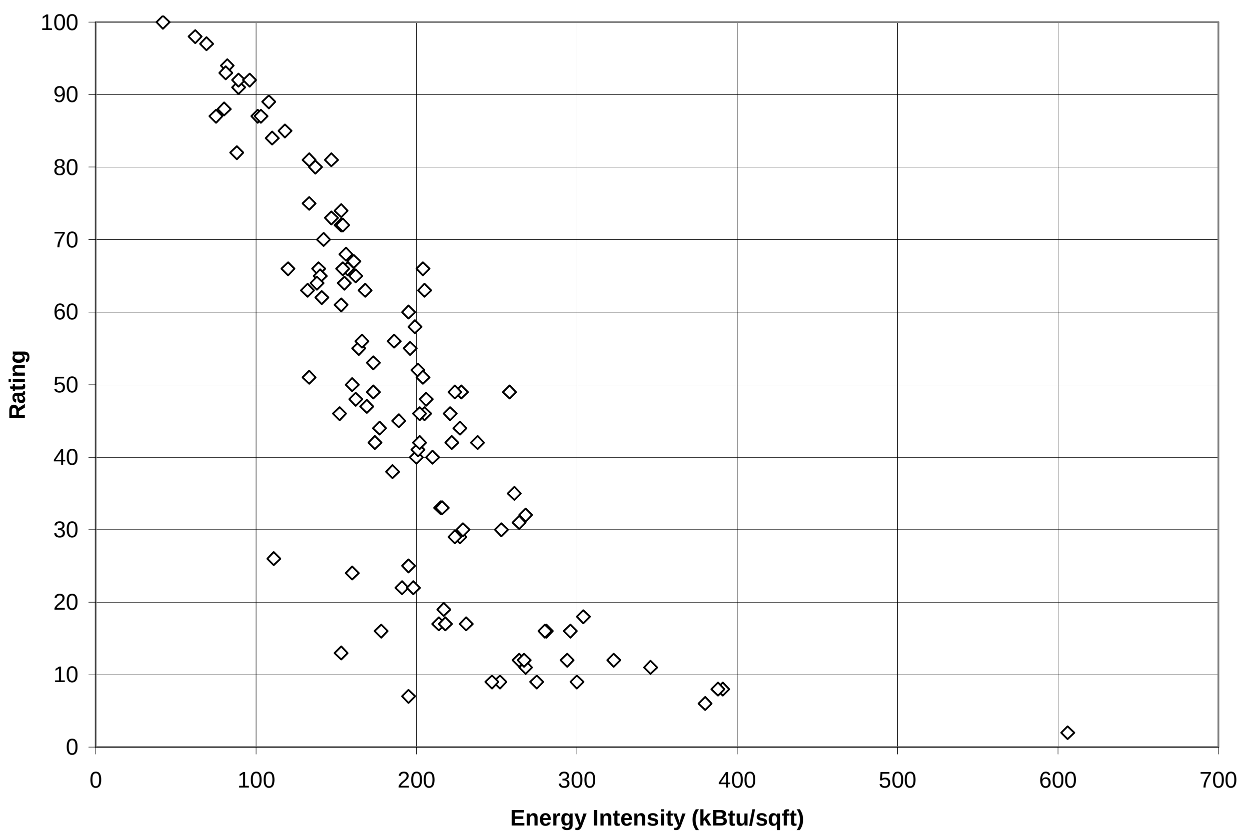


The 113 office buildings represented in the figure below, Figure 18, account for the largest fraction of the buildings in the supplementary building database. Applying a linear regression model to the graph results in the equation with an R^2 of 0.64

$$y = -0.269x + 99.949$$

In this case, the Y-intercept representing a building with net-zero energy use is 99.9, essentially the maximum value of the ENERGY STAR rating. The X-intercept of 371 kBtu/sqft represents the energy intensity for a rating of zero. The distribution of intensity values for a given rating increases with decreasing rating, the same trend as seen in several of the input sensitivity cases.

Figure 18 –Supplementary Office in ENERGY STAR



4.7 Discussion

The following conclusions may be drawn from the rating analysis performed with ENERGY STAR for Buildings on the 29 primary buildings:

- The schools showed the most diversity of ratings (57% range) followed by office (34%) and hospital (13%).
- When comparing hot and cold climate impacts, office buildings and hospitals show a small impact of less than 5% and schools average 9% with some school ratings changing by as much as 20%.
- Comparing 15% reduced and 15% increased affects the rating nearly equally. The change in rating grows smaller as the building rating is higher.

- The ratio of energy to area, the energy intensity, seems to be the driver in ENERGY STAR rather than energy or area alone.
- Number of beds or floors in a hospital has a small change in the ratings but whether or not tertiary care is offered affected the ratings 6 to 7%.
- For the one lodging building evaluated in the primary building set, the impact of reducing the "Number of Rooms" by 15% was a decrease of the rating from 96 to 87.
- The 15% reduction in the number of students changed the ratings for the school on average by only 1%.
- The fraction of school area with air conditioning seemed to change the ratings for schools by just 1% while fraction of school are with heating changed the rating by 2% to 8%.
- The ratings for Schools that operate all year were reduced by 2 to 9% when 10 months were specified but the ratings for schools already operating 10 months were not affected when the number of operating months was reduced.
- On average, a 7% reduction in the rating occurs when the input for 'cooking is performed in the building' is changed to no.
- Schools with mechanical ventilation receive a rating 10% higher than those without. This appears to be a disincentive to buildings using natural ventilation, an efficiency strategy that is gaining acceptance today.
- For schools and offices, the inputs for number operating hours per week and the number of computers present when reduced by 15%, resulted in an averaged of a 1% reduction in the rating.
- The average rating for the office buildings changed 1% when the number of occupants described for the building was reduced 15%.

The following conclusions may be drawn from the analysis of the 167 supplementary buildings with ENERGY STAR:

- Over 65% of the lodging buildings were disqualified from being rated due to the number of rooms in the building being out of range.
- The linear regression models of ratings versus energy intensity showed good agreement for the schools but not as good for the offices.
- The overall shape of the curve for office building ratings versus energy intensity showed that earning the top few points in the rating was more difficult than points in the middle of the scale.
- Not enough hospitals or lodging buildings were available to create a regression model.

While performing the analysis using ENERGY STAR for Buildings over many months, the ratings of building changed and this prompted a re-rating of the buildings to see how ratings were affected. Of the 40 building cases rated in both December 2005 and February 2006, 29 buildings showed no change, the rating for 5 buildings changed by 1 or 2%, and 6 buildings changed by 3% or more. Of the latter six, the three with the largest change were cases of hospital buildings with rating changes ranging from 7% to 15%. The author later learned through private email that the software used to calculate the ratings of buildings had been updated during this period. For another person using the web site to rate their buildings, this change in software and possible change in ratings would have been unexplained. From this experience, a recommendation is that changes to the computation process always be explained to those using the rating method perhaps even showing an explanation for any building that had a rating that is not numerically the same as the previous time the web site was used.

Some other observations made during the course of the analysis include:

- The number of workers associated with the garage space was misinterpreted by some to be the number of workers in the building served by the garage instead of the number of garage staff. A new warning for the maximum number of workers per area for garages should be added.
- ENERGY STAR already allows a spreadsheet to be used to upload the inputs for a large number of buildings. The outputs can also be downloaded for all buildings but only a small number of output variables per file. A single file that could be downloaded which contains all output results for all buildings would be a good addition.
- Although unusual, the building location input was changed during the course of the analysis and this did not impact the “last modified” date as changing other inputs did.

5 ARCH/CALARCH

5.1 Overview

The Lawrence Berkeley National Laboratory (LBNL) has two building energy rating protocols that are closely related. Cal-Arch and Arch are both protocols based on statistically valid datasets. DOE/EIA's Commercial Building Energy Consumption Survey (CBECS) is the basis of the national tool Arch, and Cal-Arch which is focused on buildings in California, uses the Commercial End Use Survey (CEUS) (partially described in PG&E 1999). The methodology used in Arch and Cal-Arch within their respective data sources is nearly identical. In Arch and Cal-Arch the buildings actual total energy use is divided by the gross floor area of the building, becoming the end-use intensity (EUI). The EUI of the building is displayed on a histogram graph that shows the frequency of EUI's for buildings in the respective databases for that type of building. The graph also shows the cumulative fraction of buildings with an EUI below a given value so that a percentile value can be determined. This approach of showing the building EUI against uncorrected and unadjusted data from a database provides a very direct understanding to the user of the protocol. Both Arch and Cal-Arch are available on the LBNL web site for use by anyone at no charge:

- Arch – http://poet.lbl.gov/arch/
- Cal-Arch – http://poet.lbl.gov/cal-arch/

The web based protocols ask just a few questions and display several different histogram graphs showing the relative position of the building entered by the user against similar data from the respective database.

5.1.1 Types of buildings

Cal-Arch is based on the CEUS dataset that includes specific categories for a variety of buildings as shown in Table 28. The building categories were mapped to roughly correspond to the CBECS categories for the Cal-Arch tool. This recategorization was performed "for consistency, familiarity, and to increase sample sizes for each category" (Kinney 2003).

Table 28 – Cal-Arch Building Categorization

Cal-Arch/CBECS Category	CEUS Category
Agricultural	Agricultural
Education	Daycare or Preschool Elementary/Secondary College or University Vocational or Trade School
Enclosed Shopping/ Mall	Shop in Enclosed Mall
Food Sales	Supermarket Convenience Store Other Food Store
Food Services (Restaurant)	Fast Food or Self Service Table Service Bar/Tavern/Club/Other
Health Care (Inpatient)	Hospital
Health Care (Outpatient)	Medical Office Clinic/Outpatient Care
Industrial Processing/Mfr	Assembly/Light Manufacturing Med/Heavy Equip. Mfg Food/Beverage Processor
Lodging (Hotel/Motel/Dorm)	Hotel Motel Resort
Nursing Home	Nursing Home
Office/Professional	Administration & Management Financial/Legal Insurance/Real Estate Other Office
Public Assembly	Recreation or Other Public Assembly
Public Order & Safety	
Religious Worship	Church
Retail (except mall)	Department/Variety Store Other Retail
Service (except food)	Gas Station/Auto Repair Repair/Non-Auto Other Service Shop
Warehouse (non-refrigerated)	Warehouse (non-refrigerated)
Warehouse (refrigerated)	Warehouse (refrigerated)

For Arch, the building categories are shown in Table 29.

Table 29 – Building Types in Arch

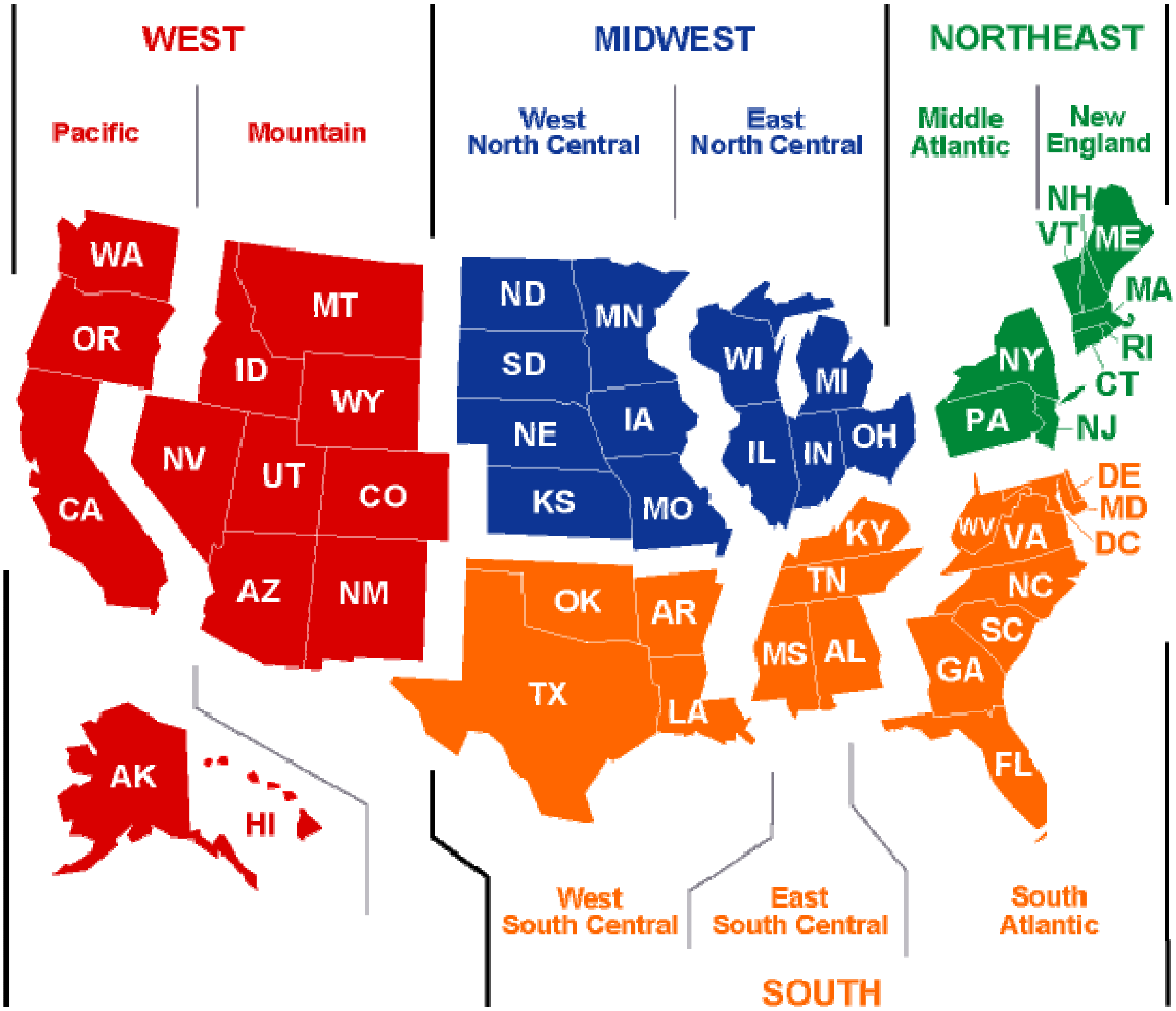
Building Type
Office Building
Laboratory
Education
Public Order and Safety
Food Sales
Food Services (restaurants)
Service (excluding food)
Health Care (inpatient)
Nursing Home
Lodging (hotel, motel, dorm)
Strip Shopping
Enclosed Shopping Center/Mall
Retail (excluding mall)
Health Care (outpatient)
Religious Worship
Public Assembly
Warehouse (refrigerated)
Warehouse (non-refrigerated)

The gross floor area is requested from the user and is used directly with the energy consumptions also provided by the user to calculate the EUI. Buildings with or without air conditioning or other end-uses may be used directly with Arch and Cal-Arch but they will be compared with the entire population of buildings in the respective databases for that building type if it includes air conditioning or not.

5.1.2 Location

Arch is intended as a national tool for the United States. The web page requests the first three digits of the ZIP code for the location of the building which "will restrict the results to buildings within the same US Census Division" according to the Arch web site, see Figure 19.

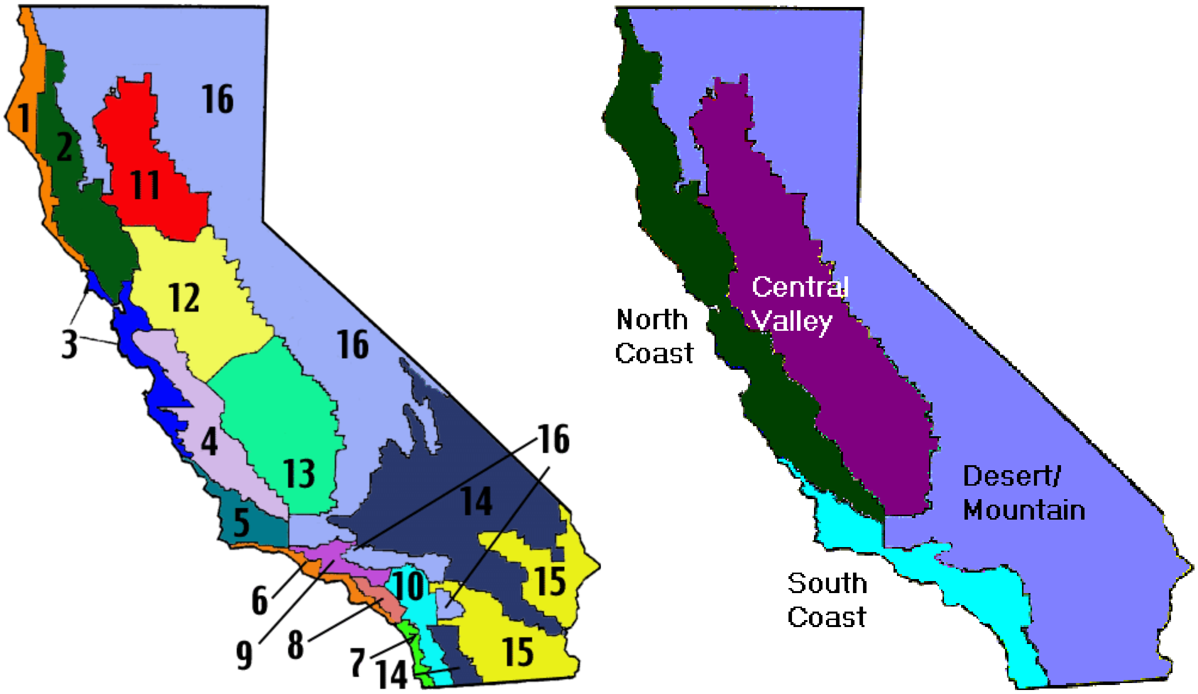
Figure 19 – The Nine Census Divisions used by Arch



Source: http://www.eia.doe.gov/emeu/cbecs/census_maps.html

The Cal-Arch web site indicates that the ZIP code can be entered, if desired, and states, "if a ZIP code is entered, only buildings within the same climate zone will be displayed. Use this field only if your building is within PG&E or SCE service territory." In addition, in the Cal-Arch final report (Kinney 2003) it states, "The California Energy Commission recognizes sixteen climate zones in California. As CEUS contains ZIP codes, these are easily mapped to climate zones. For sample size purposes it is advantageous to narrow the climate zones to four categories." See Figure 20.

Figure 20 – Climate Zones for Cal-Arch



Since the user does not provide dates for the energy consumption data, it is very unlikely that any type of adjustment for actual weather data is made. In addition, no compensation is made for micro-climate effects since the ZIP code is used to select the climate region.

Arch and Cal-Arch can be used with care outside their normal territories (the United States and California, respectively). In another location, the climate should be matched to the appropriate area by comparing long term climate variables such as heating and cooling degree-days, average relative humidity, and altitude.

5.1.3 Qualifications

Both Cal-Arch and Arch are tools that may be used for a variety of purposes to help understand how the building being analyzed compares to other buildings of the same type but no type of certification is associated with obtaining a specific percentile score. Because no certification is associated with the use of Arch or Cal-Arch, no other requirements concerning the building comfort or interior conditions are placed upon its use. If the building uses little energy because it has inadequate light or heat, someone can still use Arch or Cal-Arch and publicly state that the building obtained a given percentile score.

5.1.4 Audience

A Cal-Arch brochure states that results will be useful for:

- Building owners
- Energy managers
- Control companies
- Energy information system vendors
- Utilities
- Energy service companies
- Performance contractors
- Researchers
- Analysts

Since the protocols use utility bill information, building size and location as the only parameters, they could be used by anyone with access to utility bills and interest in their building performance. This might also include building operators, facility managers and simply the person that is responsible for paying or approving the utilities bills for an organization.

It is also possible to use Cal-Arch or Arch during the planning and implementation of a major building renovation that includes energy related upgrades. In that scenario, architects, mechanical engineers, and other members of a design team may also ask for utilities bills in order to provide a baseline estimate of the future performance of the building.

5.1.5 Ease of Use

The inputs for both Arch and Cal-Arch are a single web page. No registration is required to use the service and results are delivered in a few seconds. Unfortunately, to completely understand the output requires some experience in understanding graphs, statistics and building energy analysis. Few building operators have been trained to understand these issues.

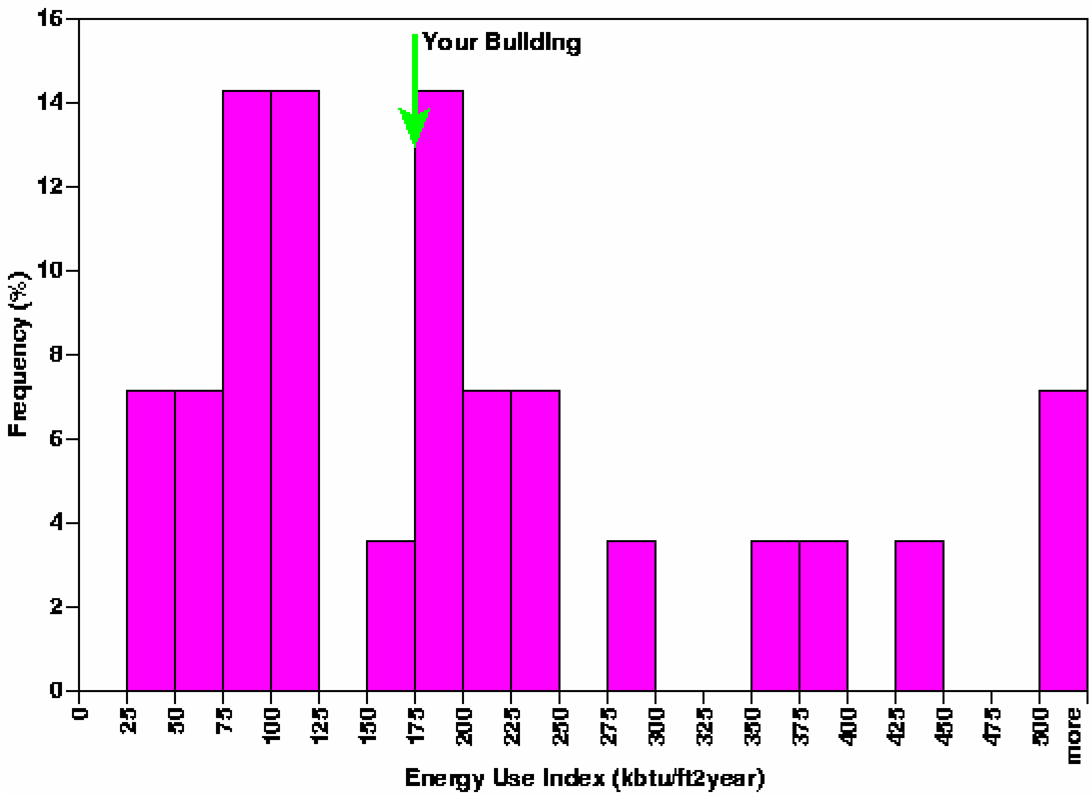
For Arch, the seven step input process is:

1. Selecting the principal activity of the building from a pull down list
2. Entering the first three digits of the ZIP code
3. Entering the floor areas as gross square feet
4. Entering the annual energy consumption
5. Choice of reporting as site or source energy consumption
6. Checkbox if data entered may be saved and added to database.
7. Proceed to the results.

When entering the annual energy consumption, the user has a choice of kWh per year or MWh per year for electricity. For natural gas the choices are: therms per year, thousand cubic feet per year, or million Btu per year.

The results are shown graphically. Only one type of graph (see Figure 21, below) is available from ARCH.

Figure 21 – Histogram results from ARCH



Along with the graph is the following explanation "The green arrow indicates your building's energy use. This graph is of **source** energy (rather than site energy) so the number may be higher than other numbers that you have seen. You entered a Floor Area of 5,500 square feet, so buildings with areas between: 2,750 and 11,000 are used. The number of buildings on this graph is **27**. Your building consumes 960,500 kbtu/year of energy, which is 175 kbtu/ft^{2}year."

For Cal-Arch, the input requested is very similar to Arch and consists of:

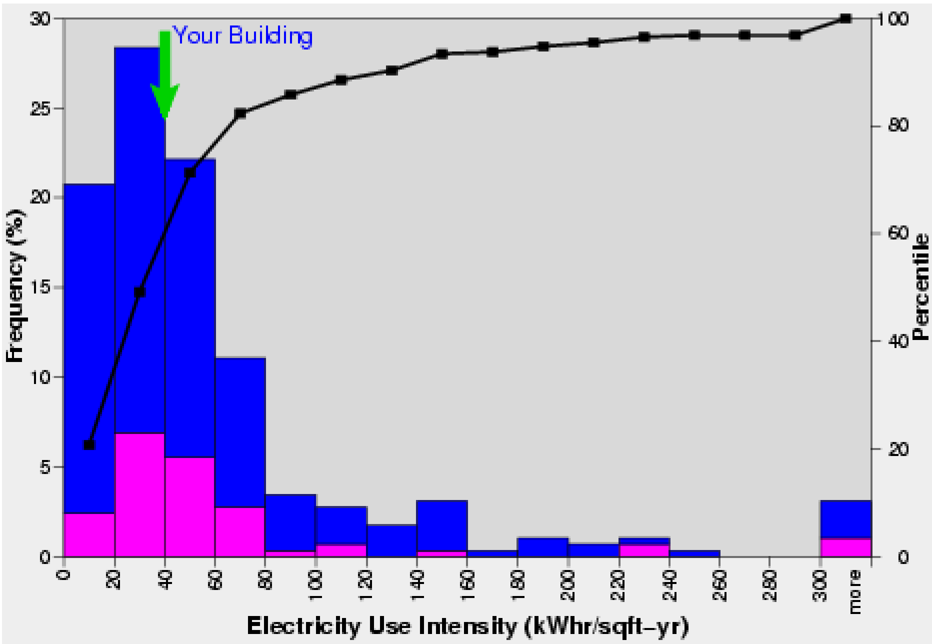
1. Selecting the principal activity of the building from a pull down list
2. Entering the floor areas as gross square feet and check a box if only want to display buildings with comparable floor area (half to double floor area).
3. Entering the annual energy consumption including a check box if the data is for whole building energy use.
4. Entering the ZIP code
5. Choice of reporting as site or source energy consumption
6. Choice of histogram, cumulative percentage or both graph types.
7. "Do the comparison" button.

The same choices for entering energy consumption data in different units are used as in Arch. The results screen includes several graphs including

- Whole building energy use
- Electricity use
- Natural gas use

For example, the electricity use graph is shown below in Figure 22. Note that the bars colors are defined as "PG&E CEUS" and "SCE CEUS" and represent actual buildings.

Figure 22 – Histogram with Cumulative Percentage Graph from Cal-Arch



The quartile values (energy use intensities for 25%, 50, 75% and 100%) for the different graphs are also shown. Many of the terms used are defined using a link to a glossary. An additional page of help is present to help the user interpret the results presented. Interestingly, the following statements are on that help page:

> *A low energy use does not necessarily mean your building is efficient and a high energy use does not always mean that it is inefficient. There are many other building characteristics not included in this tool that may affect your building's energy use. Factors such as structure, level of service, and occupancy might be different in the buildings represented on the histogram. Many buildings considered to be efficient still have significant energy savings potential; exact savings measures and potential can be determined by a qualified energy engineer.*
>
> *This tool is intended to be a starting point in assessing energy savings potential. It provides you with a direct comparison to actual data from real California buildings. We have not adjusted the data in anyway to compensate for differences in buildings. While there is benefit to doing so, it is not our intention to create a ratings system using this tool.*

Overall, once utility data and building size data is gathered, the use of the Arch or Cal-Arch rating protocol is very quick, taking only a few minutes.   The single page form with a single page of results allows for efficient entry of information. The major deficiency is that the results must be interpreted carefully. Unlike a rating system that provides a score, a building's energy use is represented as a histogram and percentile graph that makes understanding where the building stands more difficult. A clearer indication of efficiency would be more helpful to the majority of users without a building energy analysis background. No further guidance is provided on what end-uses may be causing a large amount of energy use. Having no additional guidance is similar to other protocols including ENERGY STAR. Unlike some of the other protocols, no suggestions on how to upgrade a building are provided.

5.1.6 Use Statistics

Cal-Arch has been used hundreds of times. Two specific users who have exercised the rating method extensively are (Piette 2004):

- The Pacific Energy Center
- Quatum Consulting in their retro-commissioning program.

Arch has been used minimally and has no outreach to encourage use.

5.1.7 History

The timeline for Arch and Cal-Arch is shown below. Cal-Arch was developed based on the Arch work but used the CEUS database instead of the CBECS database. All development was by LBNL.

- 1999 – Arch
- March 2001 – Current version of Arch
- July 2001 – Initial version of Cal-Arch
- July 2002 – Enhanced benchmarking database for Cal-Arch
- May 2003 – Update to remove weighting for Cal-Arch

During the development of Cal-Arch, ENERGY STAR Label for Buildings was examined but it was decided to use the EUI's for buildings directly out of the CEUS database without adjustment.

5.1.8 Rating Cost

Both Arch and Cal-Arch are free tools that anyone can use as often as they would like. No limits to the use are described on those web pages. A simple disclaimer appears on the Arch input page: "LBNL provides no warranties on the data provided: Use at your own discretion."

5.2 Technical Basis

5.2.1 Empirical Data

Arch is based on the Commercial Building Energy Consumption Survey (CBECS) data from the Energy Information Administration (EIA) of the U.S. Department of Energy. This database, which is updated every few years, contains information from thousands of buildings and the data is publicly available. More information about CBECS is described in the ENERGY STAR Label for Buildings section of this report. Arch used the 1995 version of the database and is unlikely to be updated in the future (Piette 2004).

Cal-Arch is based on part of California's Commercial End-Use Survey (CEUS). The CEUS survey is conducted by electric utilities and covers only buildings in their service territories. Cal-Arch used the CEUS data from Pacific Gas and Electric and Southern California Edison. The data was provided by the California Energy Commission and is not available publicly or for use by ASHRAE (Kinney 2002). The data is further described on the Cal-Arch web site as:

> *1996 PGE CEUS – This survey involved nearly 1000 commercial sites chosen to represent the commercial customer base in PGE's electric service territory. While Cal-Arch utilizes the actual energy use reported in the survey, PGE's analysis and simulation results are reported in the 1999 Commercial Building Survey Report.*
>
> *1992 SCE CEUS – This survey involved approximately 700 sites of which 300 were allocated to a high-resolution survey and 400 were allocated to a low-resolution survey according to SCE's stratification methodology. The resolution of the survey does not affect the data used for Cal-Arch. The building types targeted in this survey were Offices, Restaurants, Retail Stores, Food Stores, Refrigerated Warehouses, and Nonrefrigerated Warehouses.*

1995 SCE CEUS – This survey involved about 500 locations and targeted the following business types: Hotels/Motels, Elementary and Secondary Schools, Colleges and Universities, Hospitals and Clinics, and Miscellaneous Commercial.

The PG&E CEUS data is further described in Commercial Building Survey Report (PG&E 1999). The executive summary of that report states:

The Commercial Building Survey was a data collection effort involving the on-site survey of almost 1,000 commercial customers chosen to represent the population of commercial buildings in PG&E's electric service territory. This survey collected information about the customers' building structures, business operations, equipment types, fuel choices, and operating schedules. This information, along with billing data and other available customer information, was further analyzed to produce simulated end-use intensities and simulated endues sales. Data in this report were collected during the calendar years 1996 and 1997.

Little is published concerning the processing of the CEUS data but due to the expense of such a survey and the use of the survey to calibrate building energy simulation models of each building, it can be assumed that good filtering and checking of data was performed. SIC codes were used to classify building types and the survey was conducted on a per premise basis – essentially per utility customer for a given location. It is not clear how the survey participants were selected but given that the goal was to draw conclusions concerning commercial buildings in California, it is assumed that they were selected to be representing the entire population. Essentially all CEUS records were used in the database that represents all vintages of buildings.

The intention stated (Kinney 2002, Kinney 2003) is to keep updating the database used for Cal-Arch to include new versions of CEUS and utilize other databases such as U.S. General Services Administration and the Non Residential New Construction Survey (RLW 1999).

5.2.2 Use of ASHRAE standards

Neither Arch nor Cal-Arch makes use of any ASHRAE standards.

5.2.3 Documentation available

The main documentation for Cal-Arch:

- Development of a California Commercial Building Energy Benchmarking Database (Kinney 2002)
- California Commercial Building Energy Benchmarking Final Project Report (Kinney 2003)
- Cal-Arch Software Specifications Document (Piette 2001)

No specific publications are known for Arch but the Cal-Arch papers include some description. In addition, the following paper describes a survey of benchmarking tools:

- Preliminary Assessment of Building Energy Benchmarking Tools (Piette 2002)

5.2.4 Calculation details

Very few steps of calculations are required to transform the input provided by the user into the output. The energy consumptions are converted into common units and the fuels are combined by straight addition for site energy totals or using site to source conversion factors for source energy. The site to source conversion factor for natural gas is 1.0 and for electricity is 2.7. After this, the energy use intensity (EUI) is calculated by dividing by the floor area entered by the user. Finally, the records from the Arch or Cal-Arch are filtered depending on the location and building type. If the "comparable floor area" check box is selected for Cal-Arch, only buildings in the size range of half to twice the floor area are displayed. The energy uses and the floor areas from the database are combined then to calculate the EUIs and are displayed in a histogram and a cumulative percentage graph.

The floor area expected by both Cal-Arch and Arch is the gross floor area of the building. Since the number of occupants, occupant productivity, hours of operation, and actual weather are not provided, they do not affect the calculations. Weather effects are ignored which means that unusually mild or severe weather for the year that the energy consumption data is from will directly affect where the building falls in the distribution. No secondary factors such number of personal computers, swimming pools, large exterior lighting, parking lot lighting, or ventilation cause any adjustment. Since both Arch and Cal-Arch only ask for the principal building activity, any secondary types of spaces in the building are ignored.

On-site renewable energy consumption would reduce the metered annual energy consumption that is the most likely source for energy consumption fields. Off-site renewable energy consumption does not factor into the calculations.

The only statistics shown are the cumulative percentage calculation and the quartile calculation and these are shown as part of the output page for each graph. When the "whole building" checkbox is checked, the position of the "your building" indicator appears on the total source and site graph as well as the electric graph. The value is also shown on the gas graph if gas is used.

5.2.5 Validation

While no experts in the design or operation field for specific types of buildings reviewed the Arch or Cal-Arch protocol, many outreach activities occurred that resulted in some feedback concerning the Cal-Arch protocol. Organizations or seminars involved in the outreach include (Kinney 2003):

- Honeywell
- Attendees at the Building Energy Analysis seminar at PG&E Pacific Energy Center
- SiliconEnergy
- U.S. Environmental Protection Agency
- California Energy Commision
- PG&E Savings By Design
- ACEEE attendees
- California Emerging Technologies Coordinating Council
- Workshop on Cal-Arch at PG&E Pacific Energy Center
- Rebuild America Technology Seminar, SCE Customer Technology Application Center
- Current Topics in Applied Statistics conference, Cal State Hayward

As far as validation during the use of Arch or Cal-Arch, if the user enters nonsensical values they are displayed graphically just as reasonable values would be. No input validation is performed (Piette 2004).

5.2.6 Weight of Energy

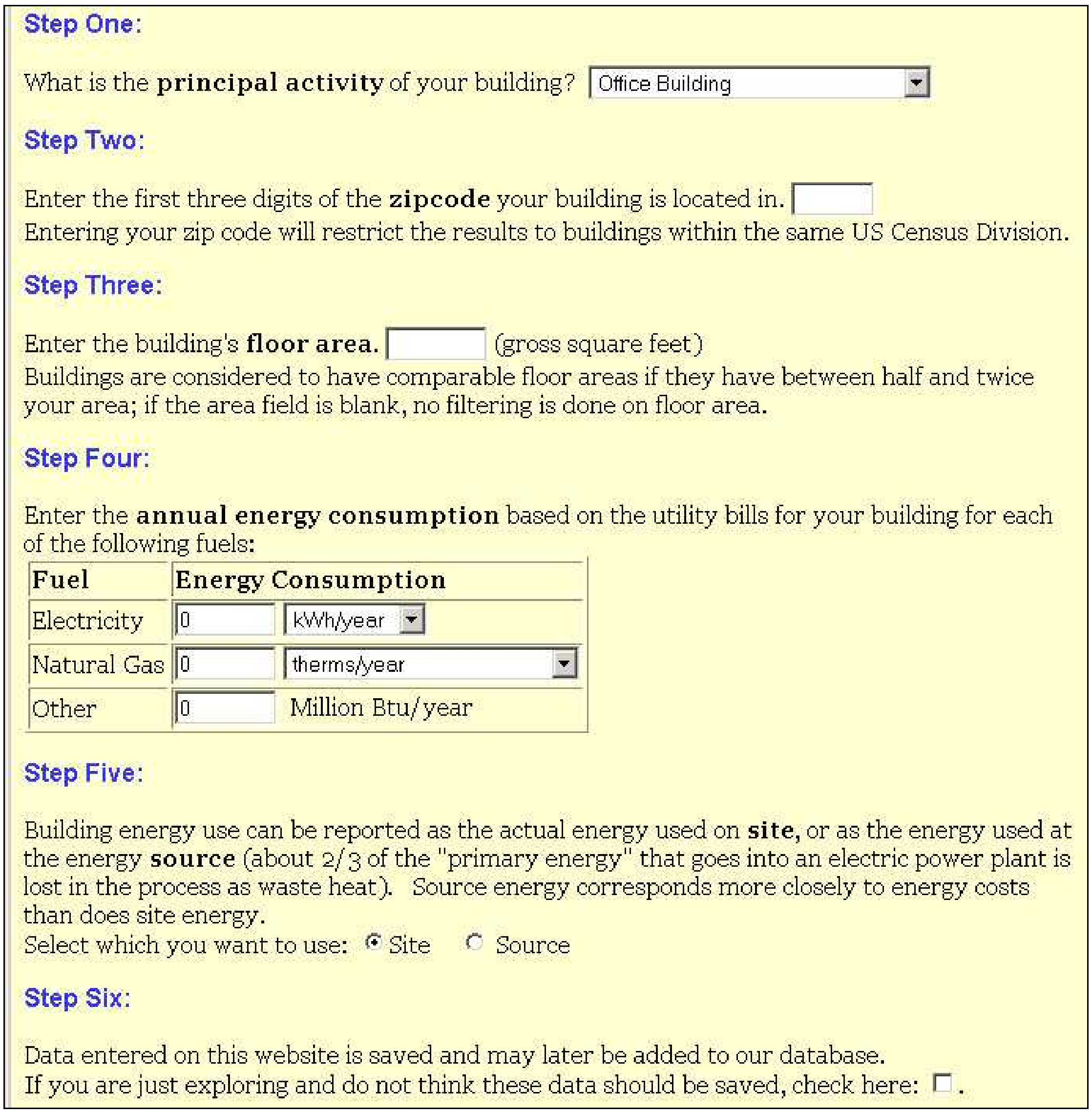
Energy use intensity is the only measure calculated as part of the protocol. The site to source conversion factor for natural gas is 1.0 and for electricity is 2.7.

5.3 Application

Combining baseline cases, input sensitivity cases and the cases based on the supplementary database of building resulted in 399 evaluations using the Arch tool at http://poet.lbl.gov/arch/. For Cal-Arch, baseline cases and input sensitivity cases resulted in 290 evaluations at http://poet.lbl.gov/cal-arch/. No supplementary database evaluations were made using Cal-Arch. Both Arch and Cal-Arch are web based energy performance rating protocols. Neither is associated with a certification program or includes a threshold or specific levels deemed as a good building. In fact, Arch does not even provide a simple numerical result of its use depending on a graphical display of how the rated building fits into the distribution of other buildings.

The next two figures, Figures 23 and 24, show the input web pages for Arch and Cal-Arch.

Figure 23 – Web Input Page for Arch


Step One:

What is the **principal activity** of your building? Office Building

Step Two:

Enter the first three digits of the **zipcode** your building is located in.
Entering your zip code will restrict the results to buildings within the same US Census Division.

Step Three:

Enter the building's **floor area.** (gross square feet)
Buildings are considered to have comparable floor areas if they have between half and twice your area; if the area field is blank, no filtering is done on floor area.

Step Four:

Enter the **annual energy consumption** based on the utility bills for your building for each of the following fuels:

Fuel	Energy Consumption	
Electricity	0	kWh/year
Natural Gas	0	therms/year
Other	0	Million Btu/year

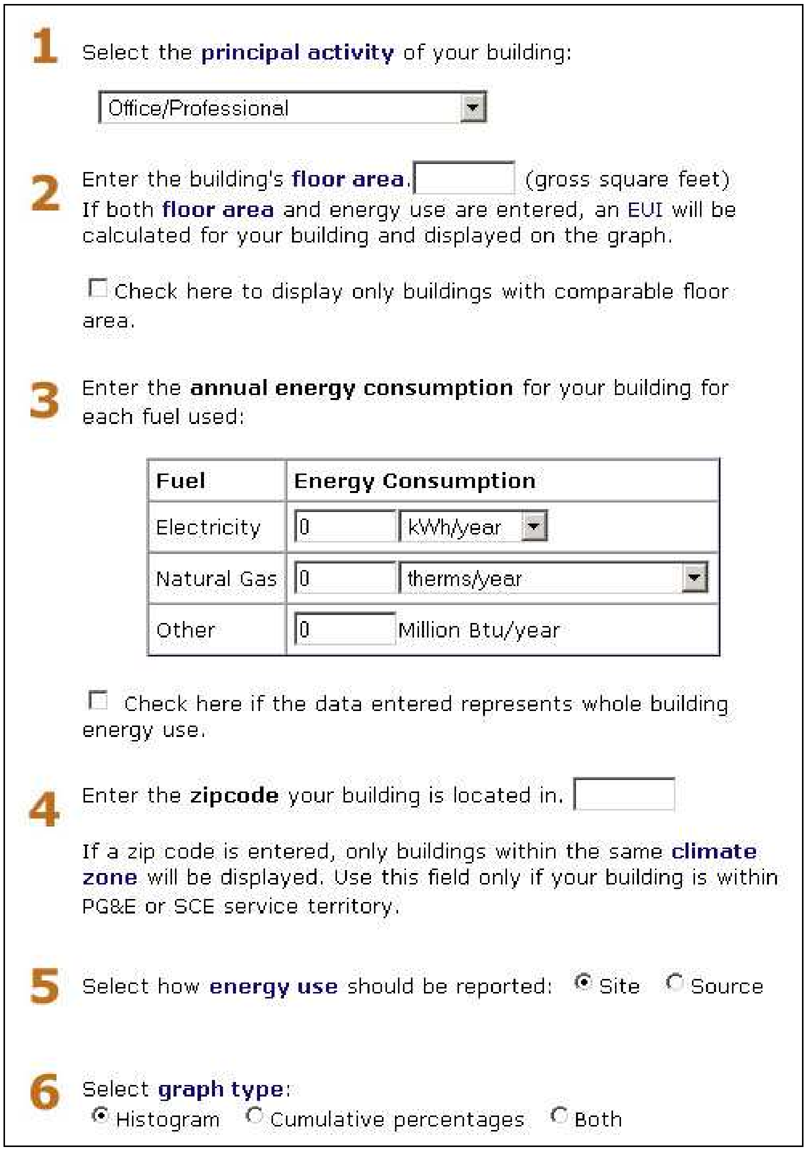
Step Five:

Building energy use can be reported as the actual energy used on **site,** or as the energy used at the energy **source** (about 2/3 of the "primary energy" that goes into an electric power plant is lost in the process as waste heat). Source energy corresponds more closely to energy costs than does site energy.
Select which you want to use: Site Source

Step Six:

Data entered on this website is saved and may later be added to our database.
If you are just exploring and do not think these data should be saved, check here: .

Figure 24 – Web Input Page for Cal-Arch



The inputs of Arch and Cal-Arch are very similar and share the following:

- Principal activity (different items in pull down list)
- Floor area
- ZIP code (only first three digits for Arch, California only for Cal-Arch)
- Annual energy consumption for electricity
- Annual energy consumption for natural gas
- Annual energy consumption for other energy
- Report in site or source energy

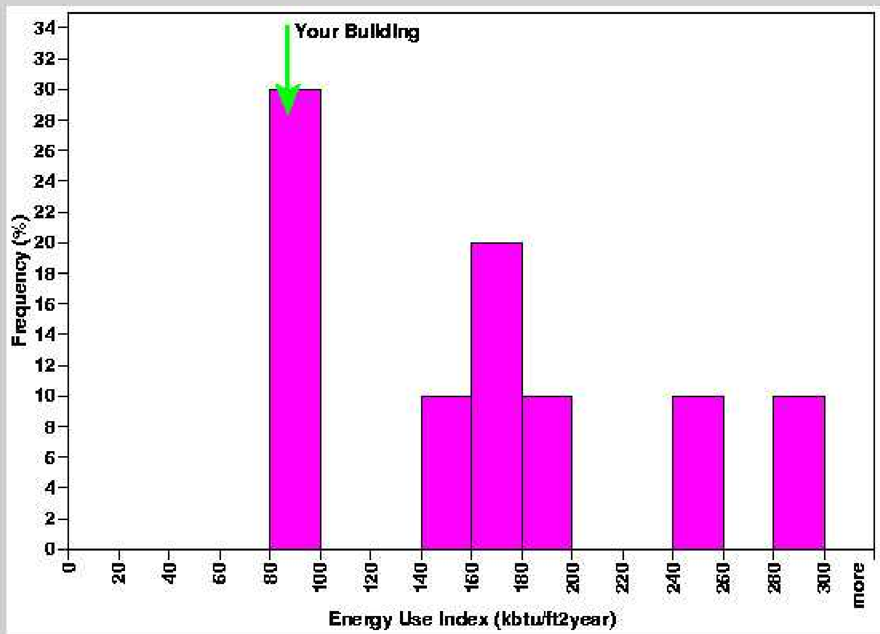
A few extra check boxes on the Cal-Arch input screen allow filtering of the results for only buildings with comparable floor areas and whether the energy consumption entered "represents whole energy use."

For Arch, the results are laid out on the web page as shown below in Figure 25. Besides the histogram of results with the "Your Building" indicator, several numeric data items are reported for each rating. Arch reports:

- Floor area entered
- Minimum of floor area range (half area entered)
- Maximum of floor area range (double area entered)
- Number of buildings on the graph
- Total energy consumption in kBtu/year
- The energy intensity in kBtu/ft2-year
- Number of buildings from a data source (usually CBECS)

Figure 25 – Arch Results

Education Building Energy Use Comparison.



The green arrow indicates your building's energy use. This graph is of **source** energy (rather than site energy) so the number may be higher than other numbers that you have seen. You entered a Floor Area of 489,000 square feet, so buildings with areas between: 244,500 and 978,000 are used. The number of buildings on this graph is **9**. Your building consumes 42,622,608 kbtu/year of energy, which is 87 kbtu/ft²year.

LEGEND

Bar Color	Data Source	# of bldgs	For further information:
	CBECS	9	Commercial Buildings Energy Consumption Survey.

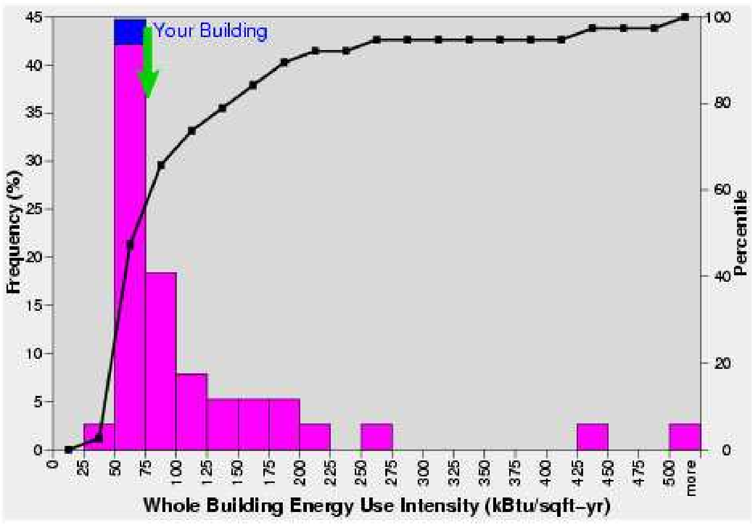
The Cal-Arch result web page, see Figures 26 and 27 below, contains three graphs for the whole building energy consumption, electricity consumption and natural gas consumption. For the whole building graph, the quartiles for the building energy intensity distribution along with the entered building energy intensity are shown in kBtu/ft2-year. A value of the percentage of the comparison buildings that have greater energy intensity is also shown. One minus this value is used throughout the analysis in this report as the "rating" of the building.

Similar values are shown for the electricity and natural gas graphs. At the bottom of the results page, a summary of the floor area and ZIP code entered are shown along with how many buildings are represented in each graph.

Figure 26 – Cal-Arch Results (Top of Page)

Education: K-12 Only Energy Use Distributions

Whole Building Energy Use

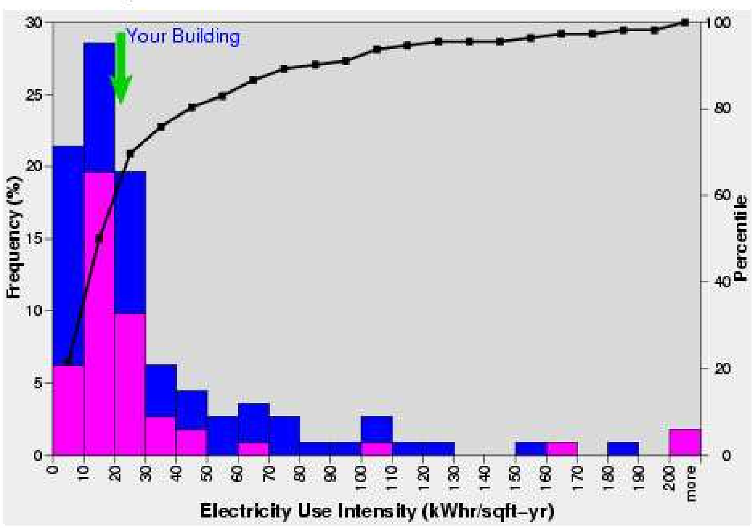


Your whole building EUI is 77 kBtu/ft²-yr, which is higher than 50 % of comparison buildings shown.

EUI Summary	
%-tile	kBtu/ft²-yr
25	60
50	77
75	119
Your EUI	77

more information

Electricity Use



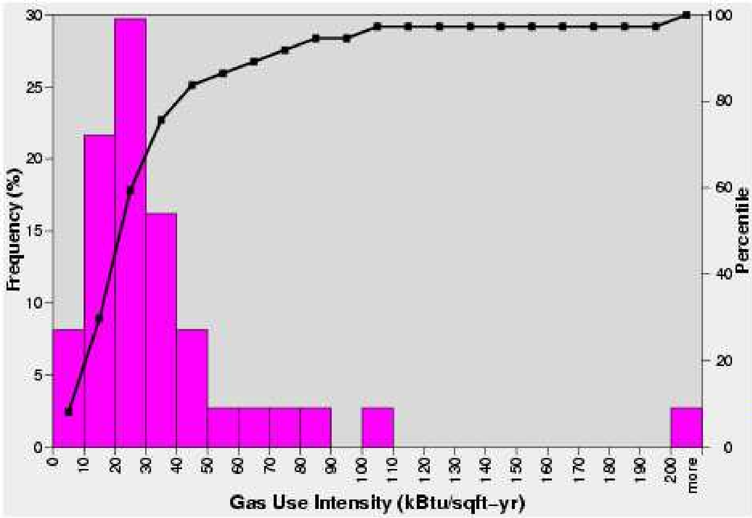
Your electric EUI is 22 kWhr/ft²-yr which is higher than 53 % of comparison buildings shown.

EUI Summary	
%-tile	kWhr/ft²-yr
25	11
50	19
75	37
Your EUI	22

more information

Figure 27 – Cal-Arch Results (Bottom of Page)

Natural Gas Use



EUI Summary	
%-tile	kBtu/ft²-yr
25	15
50	24
75	37

more information

LEGEND

Bar Color	Data Source	For further information:
	PGE	PG&E CEUS
	SCE	SCE CEUS

Description of Comparison Buildings

For this field:	You entered:	Comparison Buildings
Building Type	Education: K-12 Only	Education: K-12 Only
Zip Code	Not entered	All climate zones are shown
Floor Area	489,000 ft²	
Filter by area?	No	Buildings of all sizes are shown
Site/Source	Source	Results are displayed as source energy use

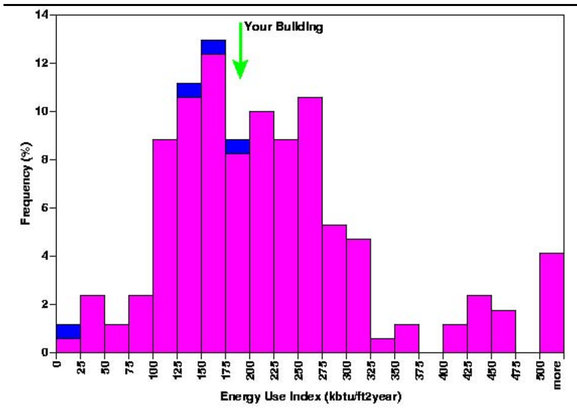
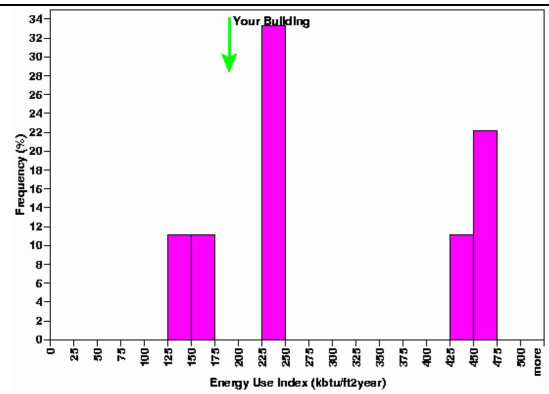
Number of buildings on graphs:

Whole Bldg	Electric	Gas
38	110	37

For this analysis, all numeric data were entered into a spreadsheet column for each case. The graphs are also copied into the spreadsheet. For Arch, the total energy consumption and the energy intensity are also computed from the original input values and are used as a quality assurance step for the data entry into the spreadsheet.

Both Arch and Cal-Arch display a frequency histogram diagram and a pointer for "Your Building" (the building being rated) as shown in the examples in Figure 28. The left example is the type of histogram desired which has a large number of buildings represented and has a shape that seems somewhat like a normal distribution. Unfortunately, the number of buildings represented in many of the evaluations is small. The histogram on the right is much more common where just a scattering of buildings is shown after choosing the building type and entering the building area and ZIP code.

Figure 28 – Examples of Arch Histograms

Desired – Many buildings in comparison	*Common – Few buildings in comparison*
	

These histogram results with only a few buildings are a challenge to interpret. They lack a large number of buildings, which leads to question just how typical are the buildings shown. In addition, in the histograms with only a few buildings means that the comparison of "higher than X percent of comparison buildings shown" may have large step changes as similar buildings with slightly different energy intensities fall in relation to the buildings on the histogram.

For Cal-Arch, the "higher than X percent of comparison buildings shown" is used as the benchmark value for the building. For Arch, this value is not shown. Instead, the histogram itself must be analyzed. The number of buildings represented by each bar is determined graphically and checked against the total number of buildings reported on the graph. The number of building above and below the "Your Building" energy intensity is then determined. If the "Your Building" energy intensity is not pointing to a bar then the "higher than X percent of comparison buildings shown" can be directly computed based on the number of buildings with higher energy intensity divided by the total number of buildings. If the "Your Building" energy intensity occurs where a bar is shown than, the percentage is computed based on the count of buildings starting with the bar just to the left in the graph (lower energy intensity) plus an adjustment based on where the "Your Building" energy intensity occurs within the bar. This adjustment is based on a linear adjustment across the bar based on the number of buildings represented by the bar. This adjustment introduces a small error that is larger if the actual distribution of buildings within the bar is clustered to one edge or another. The error is larger when fewer buildings are represented by the bar since the probability of clustering is more likely. These calculations were performed using spreadsheets.

The scale of the histograms changes depending on the buildings represented. Table 30 shows the maximum value of the X-axis is the Energy Use Index and depends on the energy use of the buildings being compared.

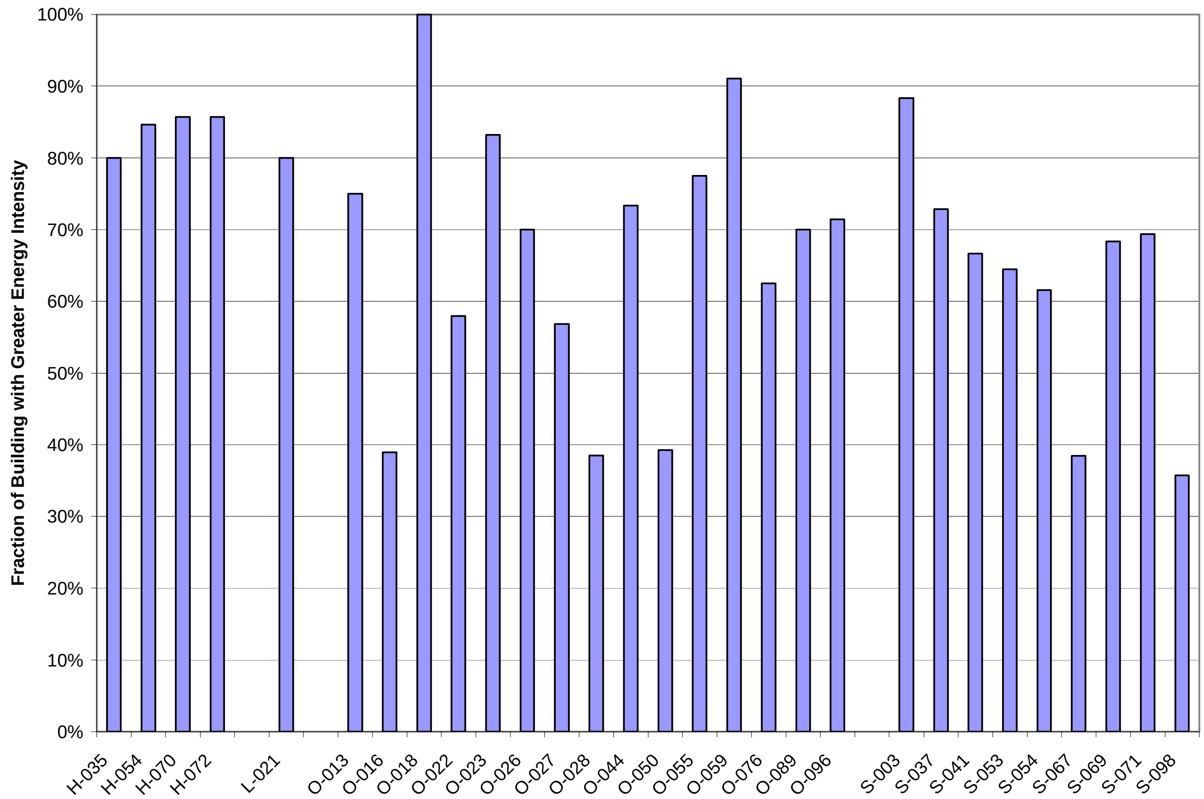
Table 30 – Scales for Energy Use Index Axis for Arch

Maximum Value (kBtu/ft2-year)	*Width of Bar (kBtu/ft2-year)*
100	5
200	10
300	20
400	20
500	25
600	40
800	40
1000	50
1200	50
1500	100

5.4 Baseline

The results of using the Arch and Cal-Arch tools to rate the 29 primary buildings are shown in Figures 29 and 30. The values shown are fraction of the buildings with greater energy intensity than the building being rated. Cal-Arch provides a value in the form of “Your whole building EUI is X kBtu/ft^2-yr, which is higher than Y% of comparison buildings shown.” Unfortunately, in this form, a lower percentage is better. For the purposes of this report one minus the percentage described as (1 – Y) is used so that higher values and taller bars represent better buildings. The “Fraction of Buildings with Greater Energy Intensity” or “Percentage of Buildings with Greater Energy Intensity” are short descriptions of the rating process that will appear on many of the graphs on Arch and Cal-Arch and should be considered the ratings. For Arch, the average rating is 69% with the maximum being 100% and the minimum being 36%. For different building types, the range is different, with hospitals exhibiting ratings from 80% to 86% while the office buildings and schools showing wider variation.

Figure 29 – Arch Baseline Ratings



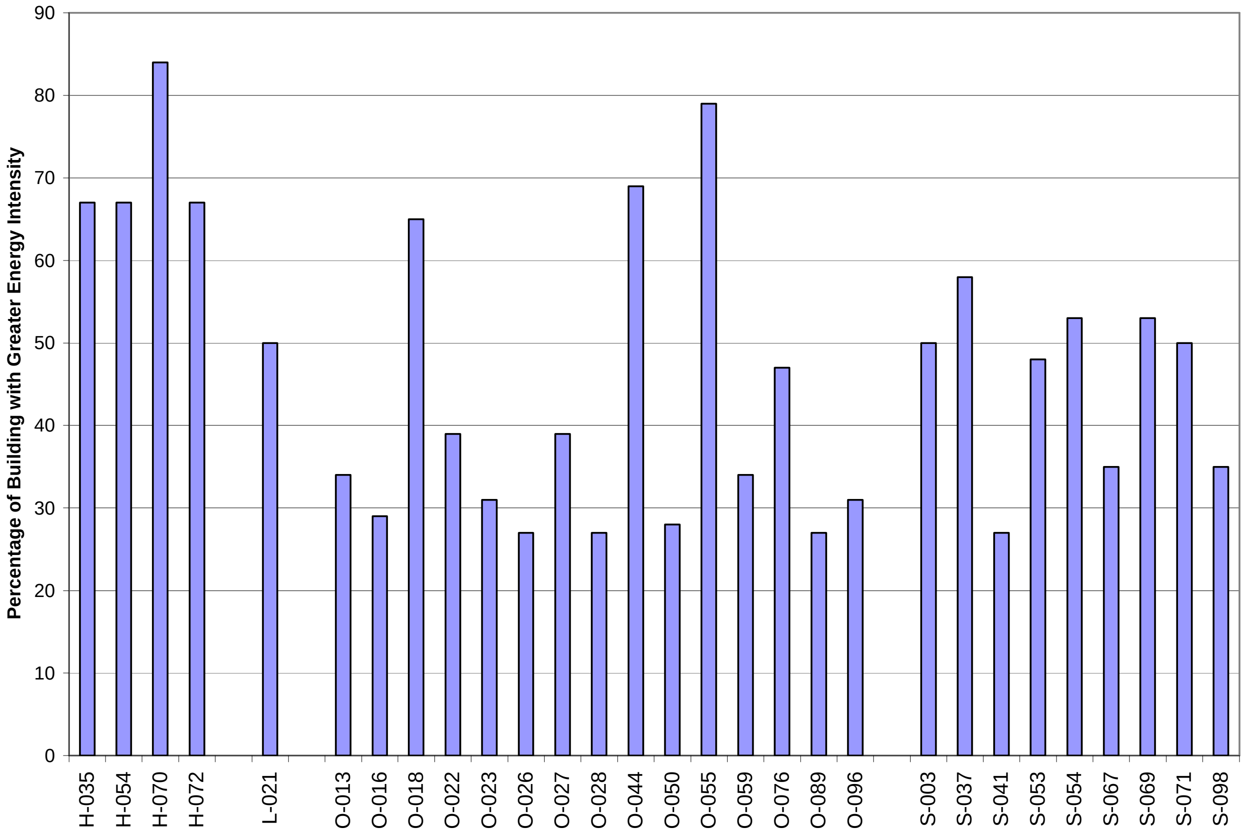
The buildings are located through out the United States but Cal-Arch is designed for rating buildings located in California. When a ZIP code is entered that is not from California, an error message is displayed instead of the normal output. Because of this, the baseline case when using Cal-Arch must use a different location than the baseline buildings actual location. While Cal-Arch allows entry of any ZIP code in California, they all are mapped into one of four different climate regions:

- North Coast
- South Coast
- Central Valley
- Desert/Mountain.

In addition, if no ZIP code is entered, it is compared to all of the buildings in the database for the entire state. One of the four regions, Desert/Mountain, does not contain much whole building data and the South Coast region did not contain many buildings covering the hospital and lodging building types. Due to this, the option of using no ZIP code at all was chosen as the baseline case.

Similar to Arch, the Cal-Arch results, Figure 30, are all presented as one minus the value provided by Cal-Arch so that the taller bars represent better ratings. Here the maximum and minimum ratings are 84% and 27% with the average rating being 47%.

Figure 30 – Cal-Arch Baseline Ratings – No ZIP Code



Since each building rating using Arch and Cal-Arch represent where that building falls within a distribution of other buildings, it is not surprising to see that, in many cases, a highly rated building in Arch is still highly rated in Cal-Arch.

5.5 Input Sensitivity

In order to try to understand how the inputs into Arch and Cal-Arch affect the resulting building rating and the relative importance of each input, the inputs to the 29 baseline buildings where modified and rated for many permutations. These permutations are summarized below in Table 31 and Table 32.

Table 31 – Arch Permutations

Permutation ID	*Description*
<none>	Baseline
NOZIP	Blank ZIP code
COLDZIP	ZIP code for Portland Maine – New England - Census Div 1 - 04101
HOTZIP	ZIP code for Dallas Texas - West South Central - Census Div 7 – 75201
SITE	Check the site button instead of source
M15AREA	Area * 0.85
M15ENERGY	Electricity * 0.85, Natural Gas * 0.85, Other * 0.85
P15ENERGY	Electricity * 1.15, Natural Gas * 1.15, Other * 1.15

The 15% change for area and utility energy consumption was chosen to provide adequate differentiation between cases but not to push the building beyond a reasonable range.

Table 32 – Cal-Arch Permutations

Suffix for Building Name	*Description*
NOZIP	Blank ZIP code (baseline)
NOZIP-SITE	Check the site button instead of source
NOZIP-M15AREA	Area * 0.85
NOZIP-M15ENERGY	Electricity * 0.85, Natural Gas * 0.85, Other * 0.85
NOZIP-P15ENERGY	Electricity * 1.15, Natural Gas * 1.15, Other * 1.15
NOZIP-FILTERAREA	Filter by buildings with comparable floor area
VALLEYZIP	ZIP code for California Central Valley - Fresno – 93701
MOUNTZIP	ZIP code for California Desert/Mountain - El Centro – 92243
NORTHZIP	ZIP code for California North Coast - Oakland – 94602
SOUTHZIP	ZIP code for California South Coast - Pasadena - 91101

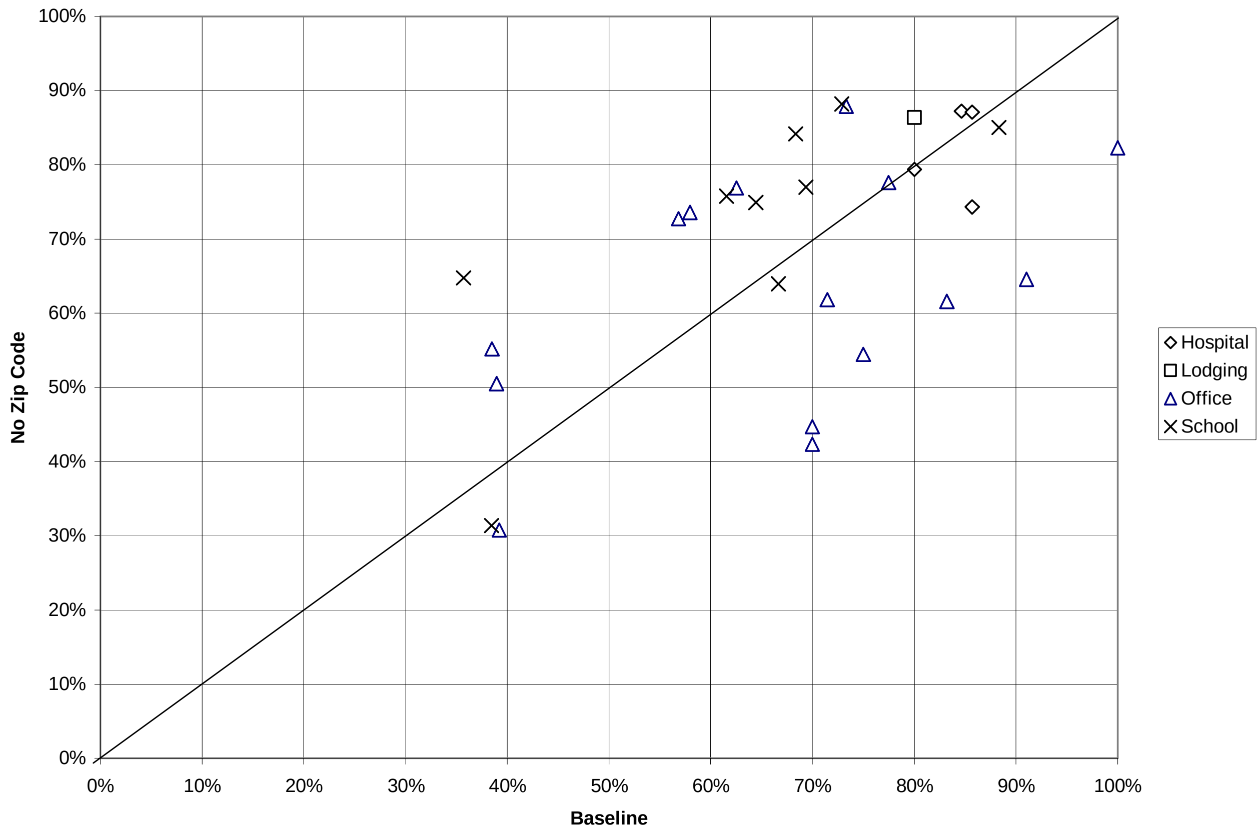
While energy codes in California recognize 16 different climate zones, Cal-Arch has combined these into four climate regions, see Table 33 below. Since the actual baseline buildings are located throughout the United States, all four climate regions are tested as part of the Cal-Arch permutations along with entering no ZIP code. The no ZIP code case compares the building with all California buildings in the database. The no ZIP code case serves as the base case for several of the other permutations

Table 33 – Cal-Arch and California Energy Code Climate Zones

Climate Zone	*Representative City*	*Region*
CZ 1	Arcata	North Coast
CZ 2	Santa Rosa	North Coast
CZ 3	Oakland	North Coast
CZ 4	Sunnyvale	North Coast
CZ 5	Santa Maria	South Coast
CZ 6	Los Angeles	South Coast
CZ 7	San Diego	South Coast
CZ 8	El Toro	South Coast
CZ 9	Pasadena	South Coast
CZ10	Riverside	South Coast
CZ11	Red Bluff	Central Valley
CZ12	Sacramento	Central Valley
CZ13	Fresno	Central Valley
CZ14	China Lake	Desert/Mountain
CZ15	El Centro	Desert/Mountain
CZ16	Mount Shasta	Desert/Mountain

Figure 31 shows the impact of not entering a ZIP code for the 29 buildings. Both axes are ratings with the X-axis being the baseline rating for a building and the Y-axis being the rating without entering a ZIP code. Two factors influence this graph. The first factor is that by comparing without a ZIP code, buildings in all climates are included in the comparison. The second factor is that the number of buildings is much larger when no ZIP code is specified since all buildings in the database similar to the rated building are included. Given these two factors, the amount of scatter is large and the no-ZIP-code results do not correspond well with the baseline results.

Figure 31 – Arch Rating for No ZIP Code and Baseline



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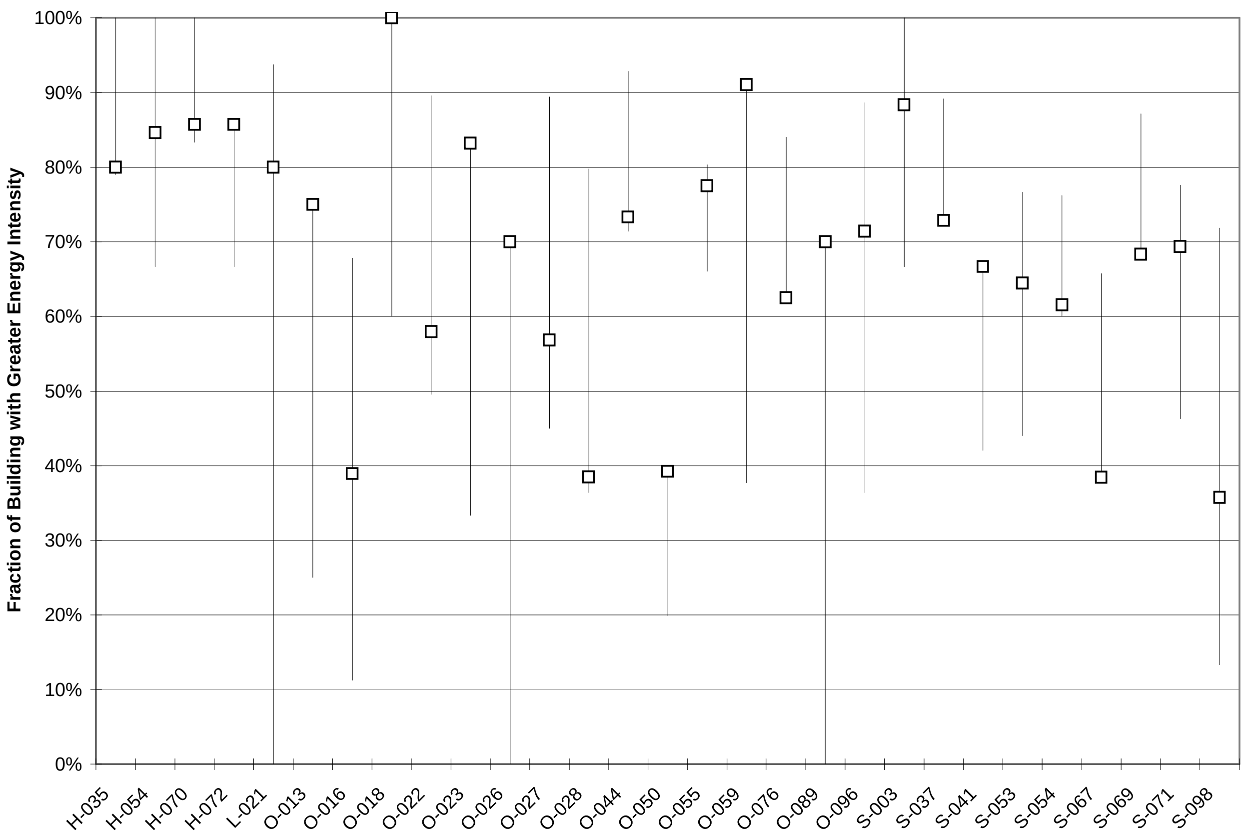
The impact of the ZIP code input can be very large. Each building was rated using Arch in two different locations to see the importance of that input. The two locations chosen were:

- Portland Maine 04101
- Dallas Texas 75201

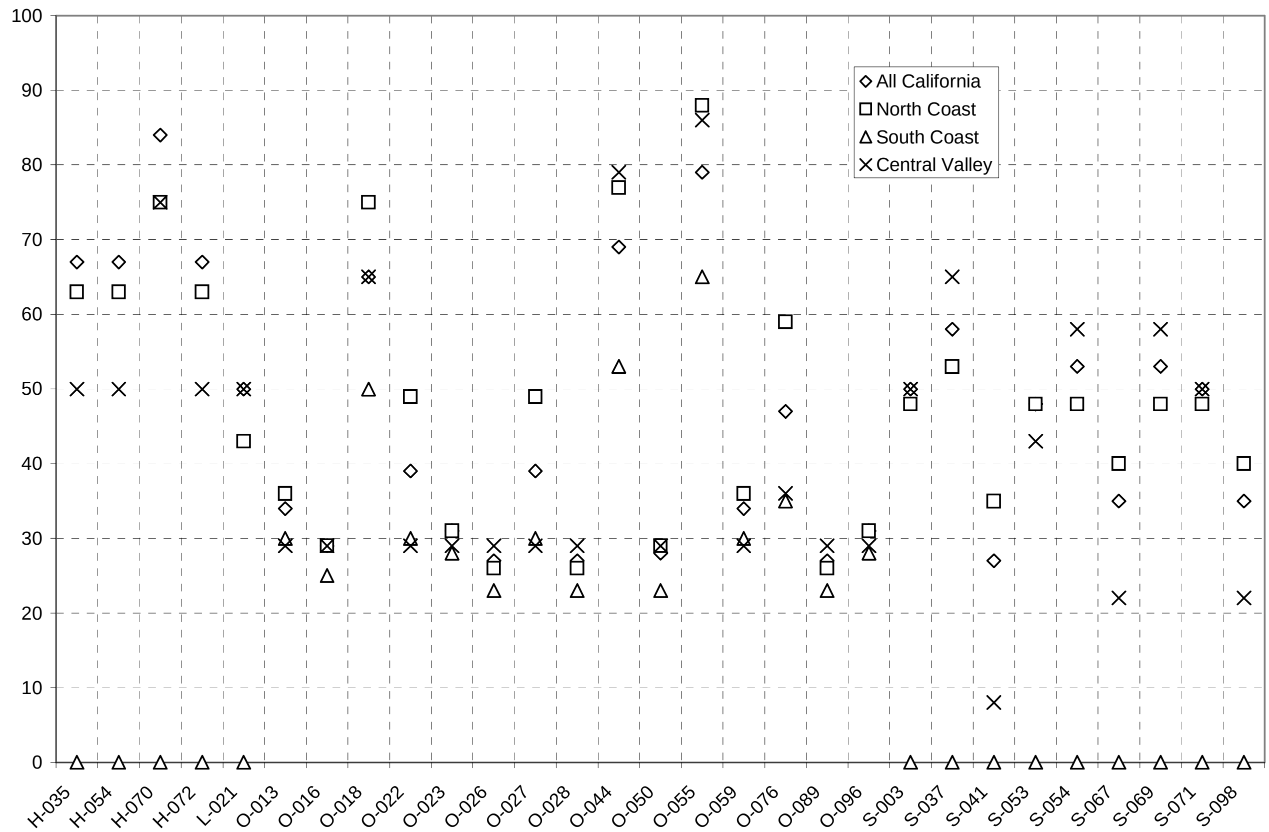
From the figure below, Figure 32, the impact of the rating on climate was smallest for hospitals, which typically are dominated by internal loads with an average spread of 23%. On the graph the box represents the baseline rating while the top and bottom of the line represent the ratings two locations. Schools had the next smallest range with an average value of 28% and offices had an average range of 41%. Generally, the rating when using Dallas was higher than when using Maine, which implies that the ratings are more driven by cooling loads. One way to think of this is that a building consuming the same amount of energy in two locations would be rated highest in Dallas and much lower in Maine. Two buildings did not follow this pattern and had higher ratings in Maine than Dallas, i.e., a hospital in the Pacific Northwest and a school in the Midwest.

Figure 32 – Arch Ratings Using Hot and Cold ZIP Codes



For Cal-Arch, each building was rated using four different climates within California as shown below in Figure 33. The Y-axis is the rating. The Desert/Mountain ratings were incomplete due to the lack of buildings in the database for those areas of California. For hospitals, the ratings for all of California were the highest followed by the rating using the North Coast region and then the Central Valley. In the South Coast ratings, both hospitals and lodging did not have enough buildings with whole building energy consumption reported to provide a rating. For office buildings, the highest ratings for most cases were from the North Coast followed by all California with Central Valley and South Coast often with the lowest rating. For some schools, Central Valley usually produced the highest rating followed by all California and North Coast. Other schools had Central Valley with the highest rating. The inconsistency in even the ordering of the results for a given building type makes drawing conclusions about climate impacts on rating difficult. It also makes using a California rating system on buildings outside of California even less reliable.

Figure 33 –Cal-Arch Ratings with Alternative Climates



Using Arch but entering 15% less utility energy consumption or 15% more energy consumption provides a much larger distribution than expected as shown in Figure 34.   On the graph, the box represents the baseline rating while the top and bottom of the line represent the ratings at the 15% less and 15% more energy consumption. For some select buildings, the impact is very small but for most, the impact is substantial.

Figure 34 – Arch Rating with Plus and Minus 15% Energy Consumption

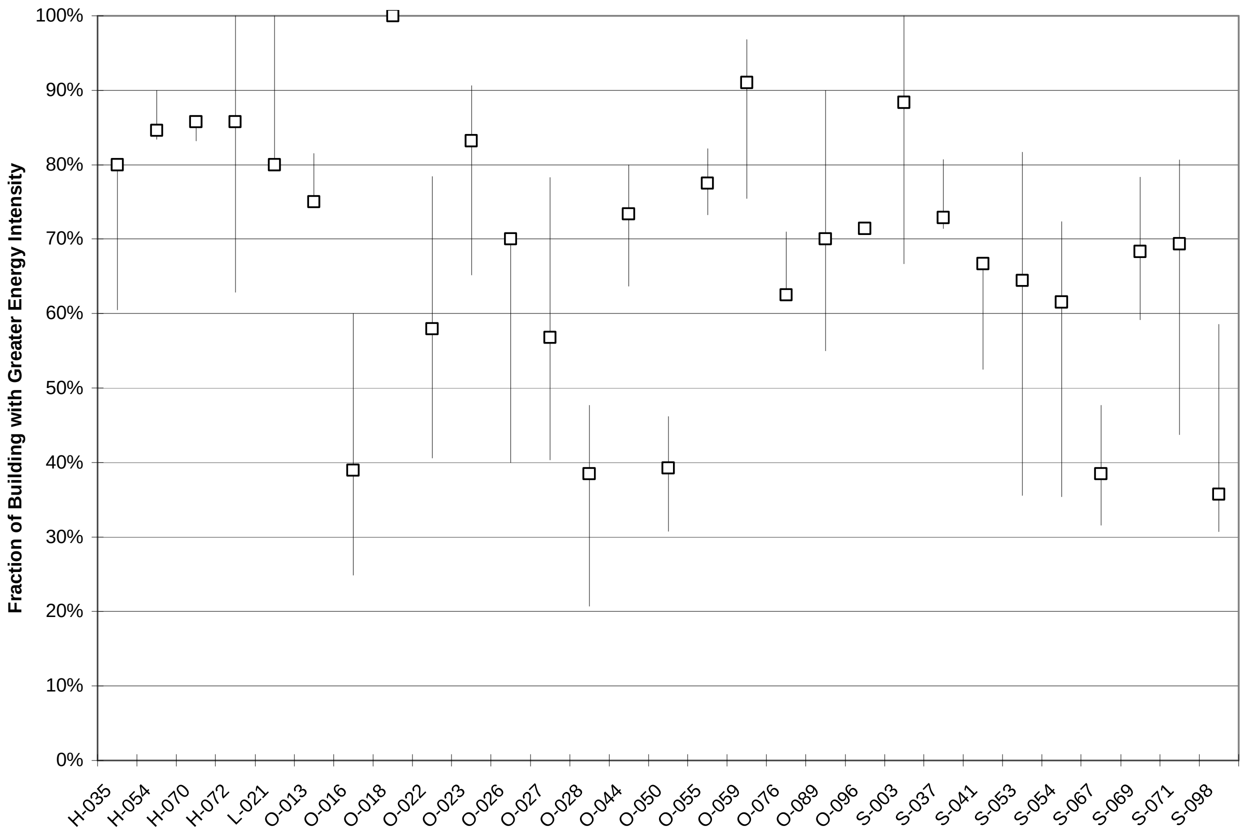
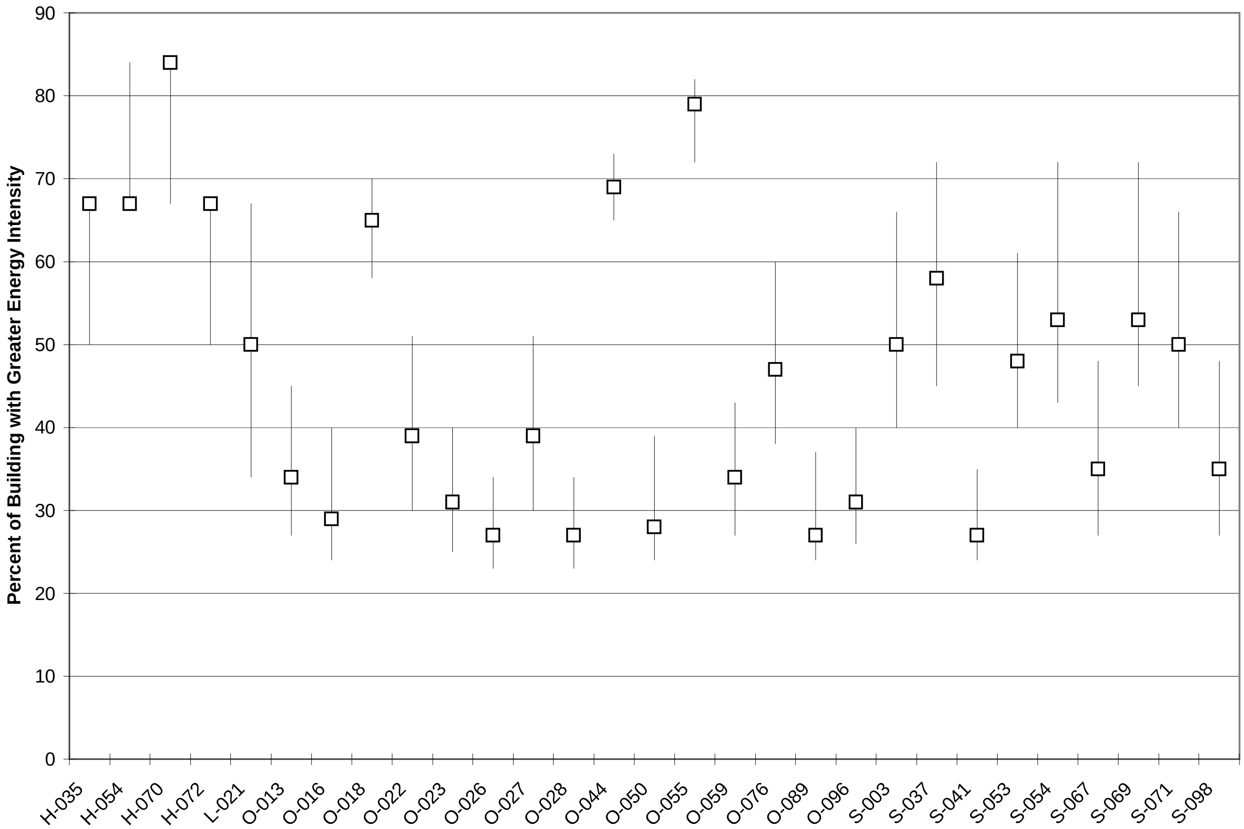


Figure 35 shows the same comparison for Cal-Arch using 15% more energy and 15% less energy. The ratings results look similar to those in Figure 30. In general, Cal-Arch seems to produce slightly narrower ranges for this test. For hospital, the range is consistently 17% while the average range for office is 15% and for schools is 23%.

Figure 35 – Cal-Arch Rating with Plus and Minus 15% Energy Consumption



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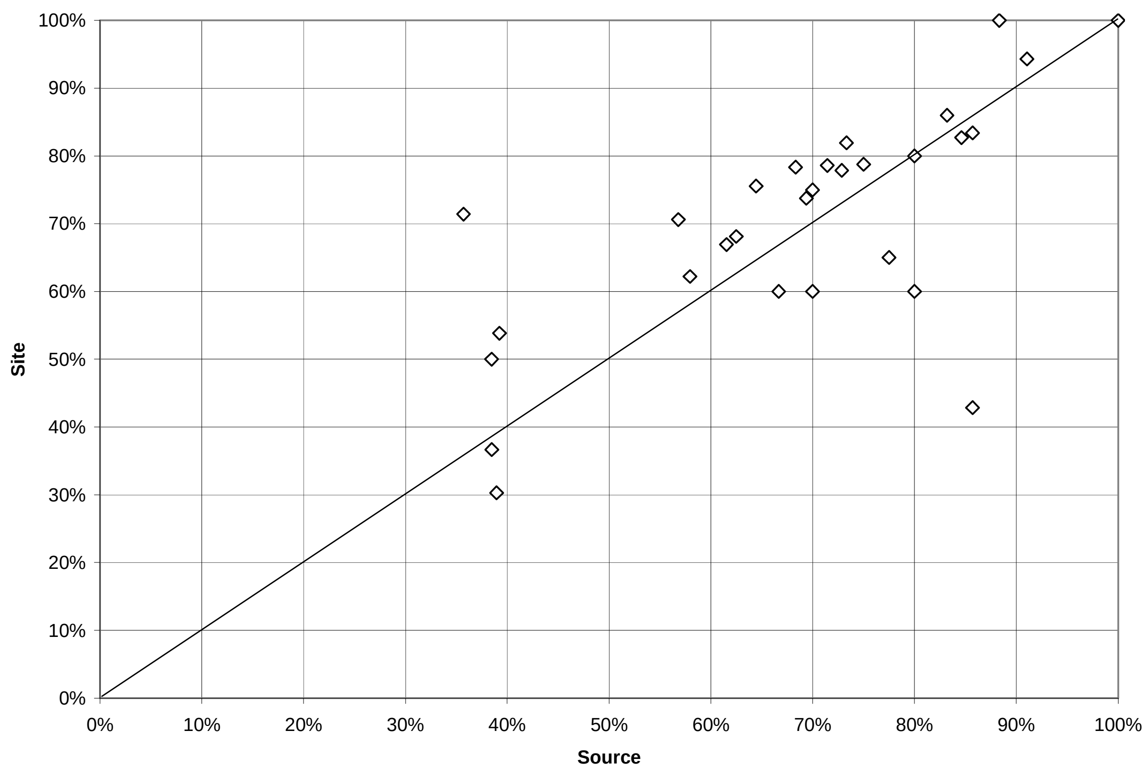
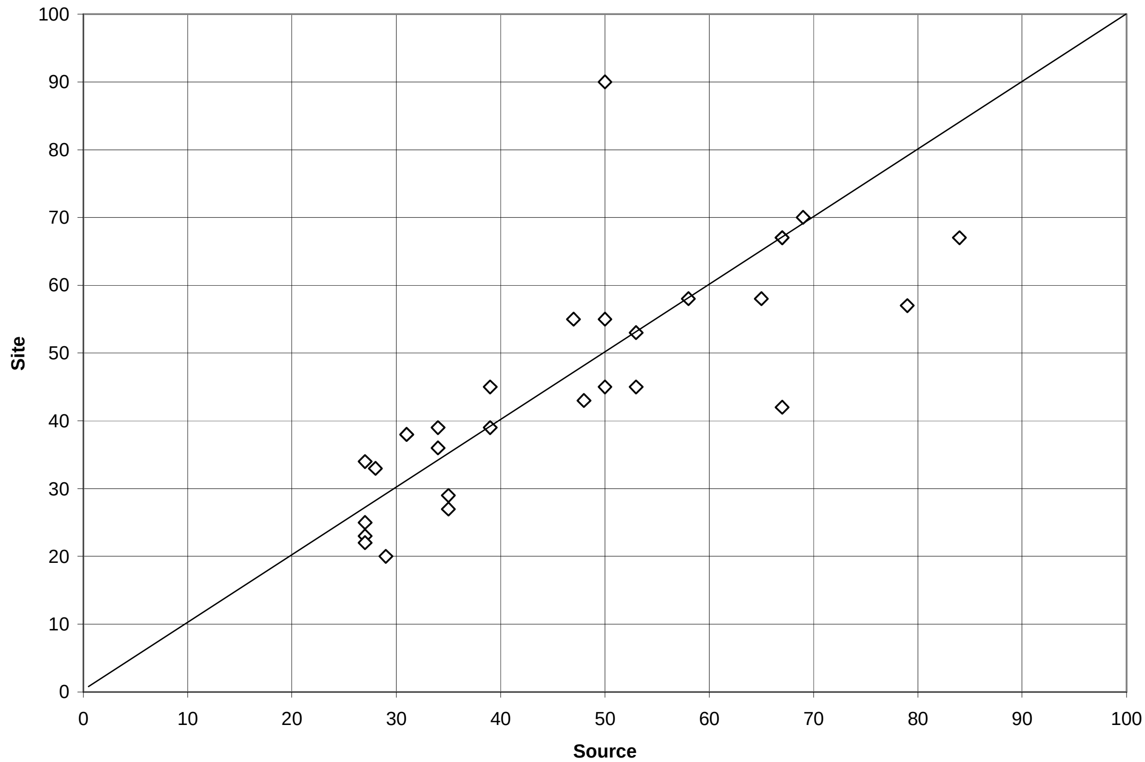
Two different methods are commonly used to measure total utility energy consumption. Source energy consumption looks at the energy ultimately consumed including losses due to power generation and energy transmission. Site energy looks at only the energy consumed at the building location by summing together the energy measured by the meters after converting to a common unit. Source energy is a better indicator for the societal impact and is usually ranks results more similar to ranking based on energy cost than on ranking based on site energy consumption. Source energy is used for all cases in this report except for ones specifically called site energy. In Arch, when site energy is selected instead of source energy, the rating is affected since the energy intensity for the benchmark building and all of the buildings in the Arch database are computed using site energy. Figure 36 shows the results of these cases where both the axes are ratings. A line from (0, 0) to (100, 100) has been added for convenience. Generally, most buildings are rated at a higher value using site energy instead of source energy. Two of the buildings are outliers. One is a hospital with a small amount of natural gas use and large "other" energy use. The other is a school with no unusual energy use. When those outliers are eliminated, the correlation is good with an R^2 value of 0.76.

Figure 36 – Source versus Site Energy Based Ratings in Arch



For Cal-Arch, the relationship between site energy and source energy ratings is similar as shown in Figure 37 where both axes represent ratings. One building, a school, is a distant outlier and when eliminating that outlier the linear regression model results in an R^2 value of 0.76. A line from (0, 0) to (100, 100) has been added for convenience.

Figure 37 – Source versus Site Energy Based Ratings in Cal-Arch



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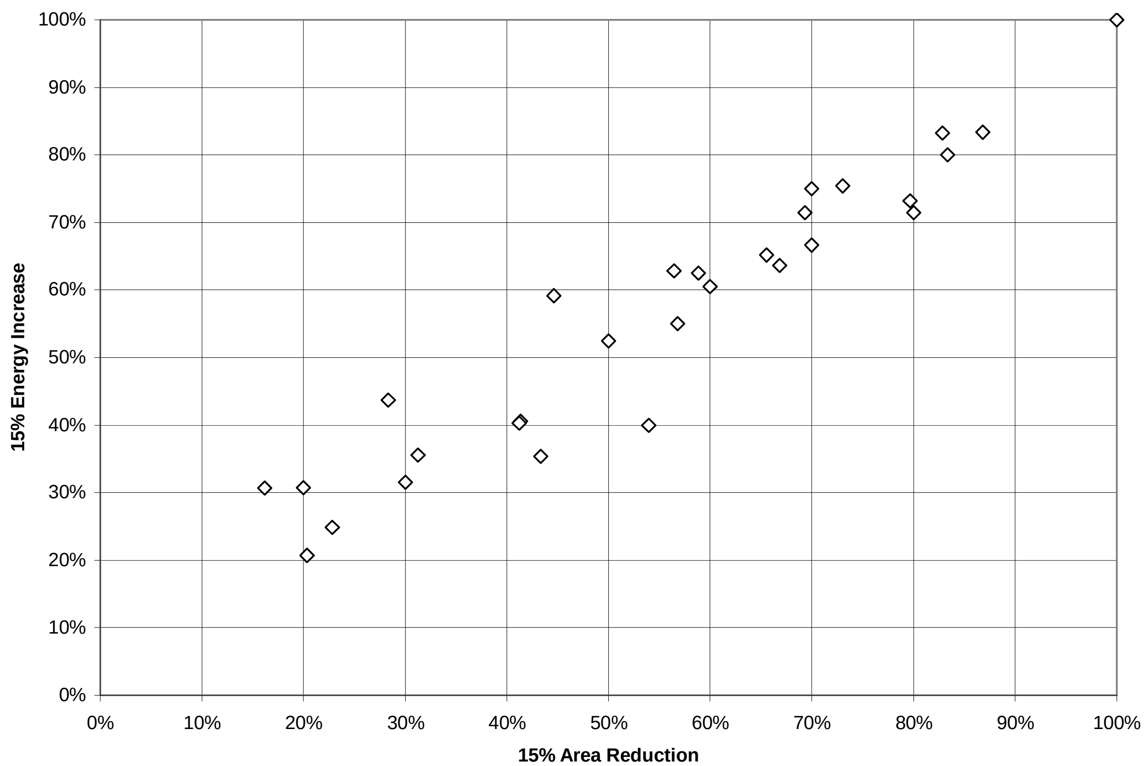
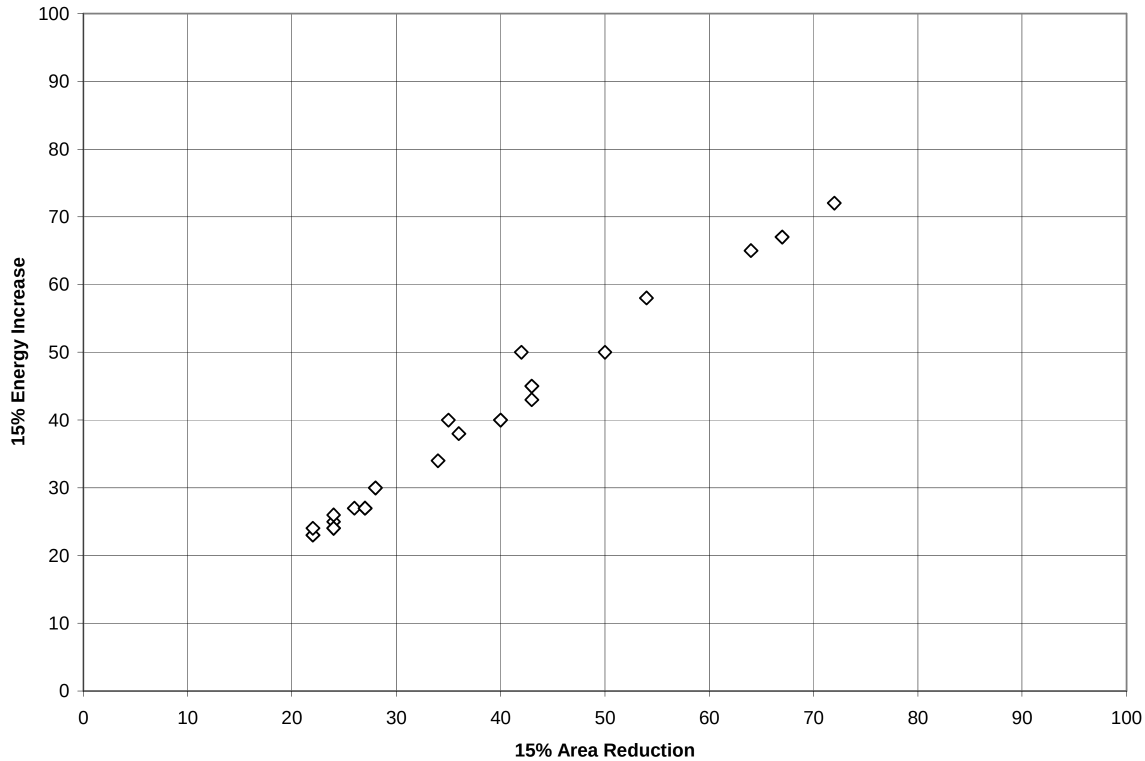
The energy intensity when reducing the floor area by 15% is very close to the energy intensity when increasing the energy intensity by 15% but the ratings are not necessarily that close under Arch because it affects the buildings used for comparison from the database. In Arch, when a value is entered for the building area, the rated building is compared against buildings that are in the size range of half that size to double that size. Figure 38 shows that they are very similar and when a linear regression model is applied the resulting R^2 is 0.89. The reason the correlation is not better is that the two cases being compared do not necessarily use the same set of buildings.

Figure 38 – Reducing Area by 15% Compared to Increasing Energy by 15% for Arch Ratings



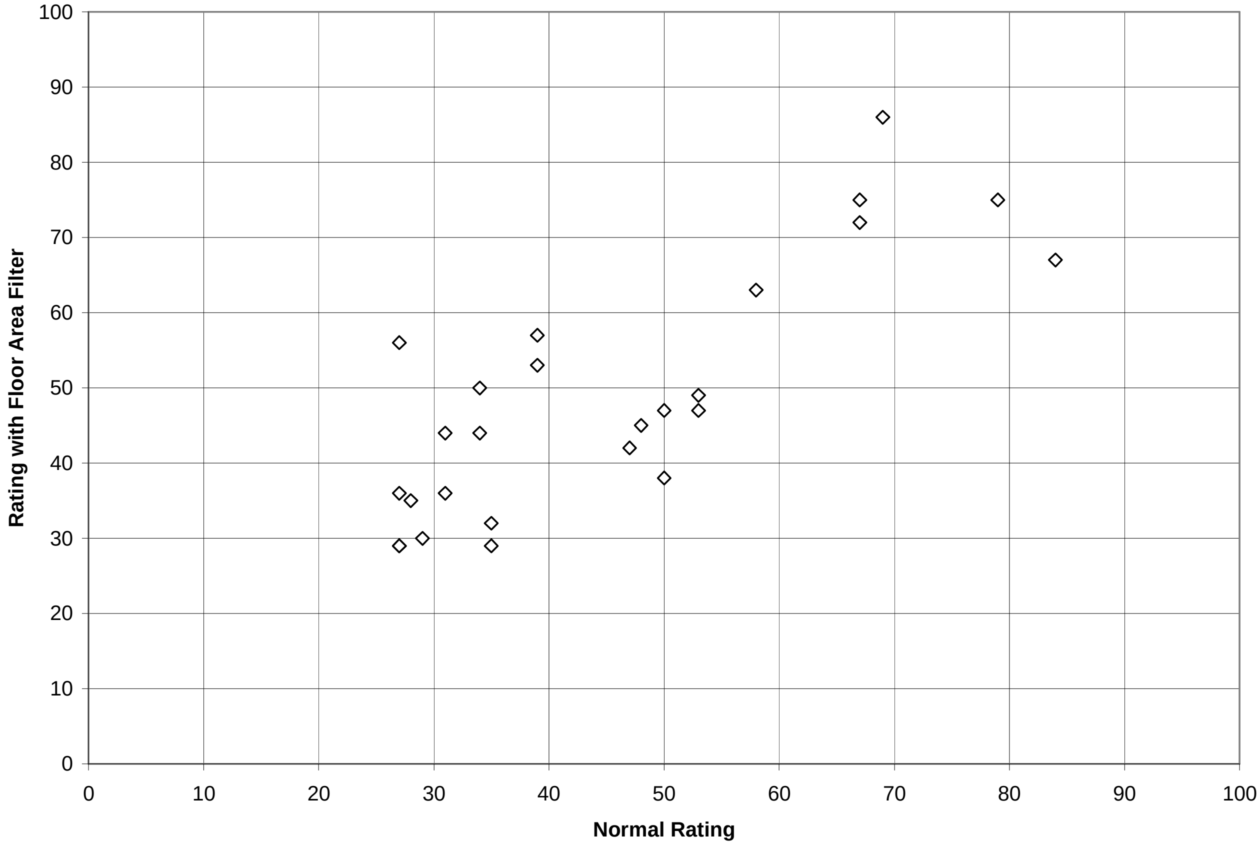
Doing the same with Cal-Arch, see Figure 39, does not affect the buildings being compared in the database of buildings since Cal-Arch has a separate selection for that function. In this case, the R^2 is 0.986.

Figure 39 – Reducing Area by 15% Compared to Increasing Energy by 15% for Cal-Arch Ratings



To illustrate the use of the input for filtering the results for only buildings with comparable floor areas, Figure 40 shows the impact of rating using that option. When the filter by comparable floor area option is selected, the rated building is compared to only the buildings that are in the size range of half the floor area to twice the floor area. This subset of buildings may be considered a better representation for comparison. Unfortunately, using this option often reduces the number of buildings being compared to such an extent that the comparison actually loses value. In the case of the 29 buildings being rated as part of this project, three had no rating when the filter by floor area option was chosen because no buildings could be compared to.

Figure 40 – Ratings Using the Area Filter in Cal-Arch



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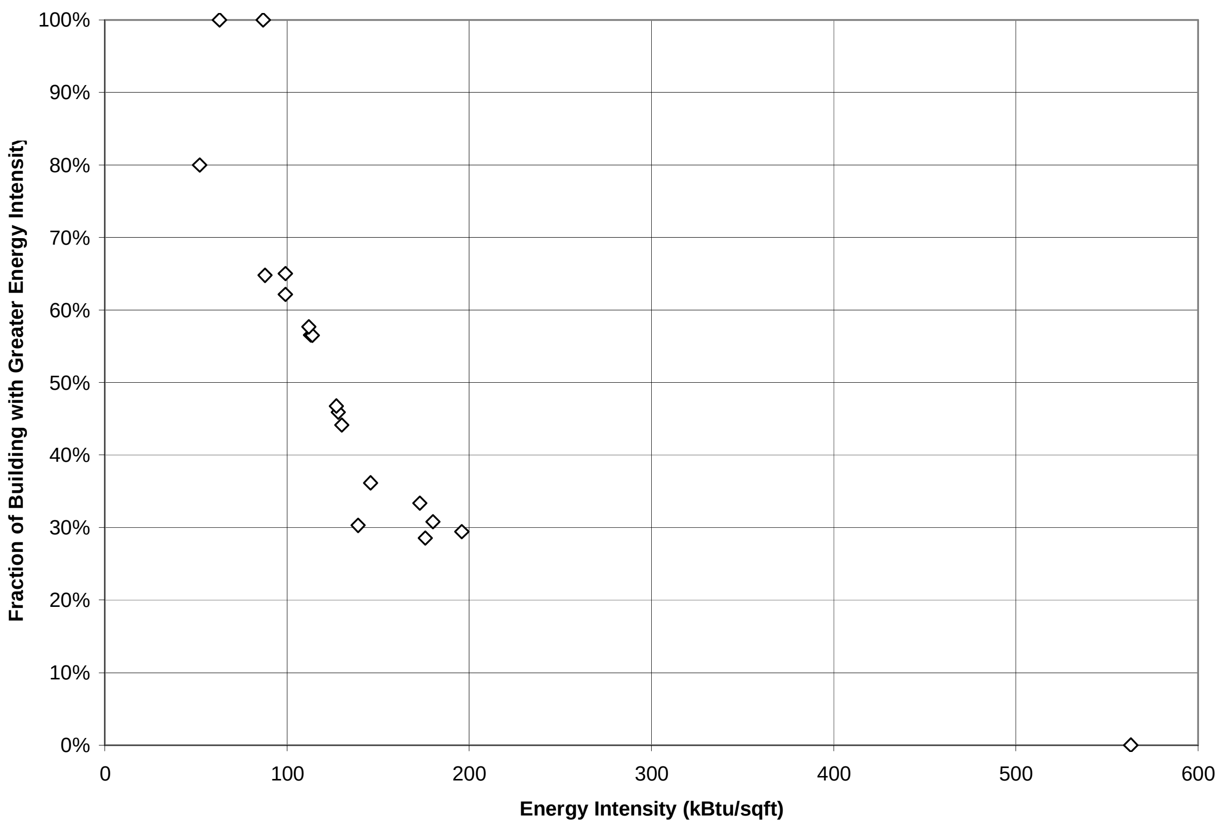
5.6 Supplementary Buildings

The larger number of buildings in the supplemental data set based on the North West Energy Efficiency Alliance's Commercial Building Stock Assessment allows exploration of general trends that may not be apparent from the smaller set of primary building data gathered for the project. For Arch, the 19 school buildings from the NWEEA database show a strong correlation with energy intensity as shown in Figure 41. The three buildings at the top and bottom of the range seem to be outliers. The remaining 16 buildings show a strong linear correlation and using least squares regression results in the following formula with an R^2 of 0.90.

$$y = -0.003932x + 0.9891$$

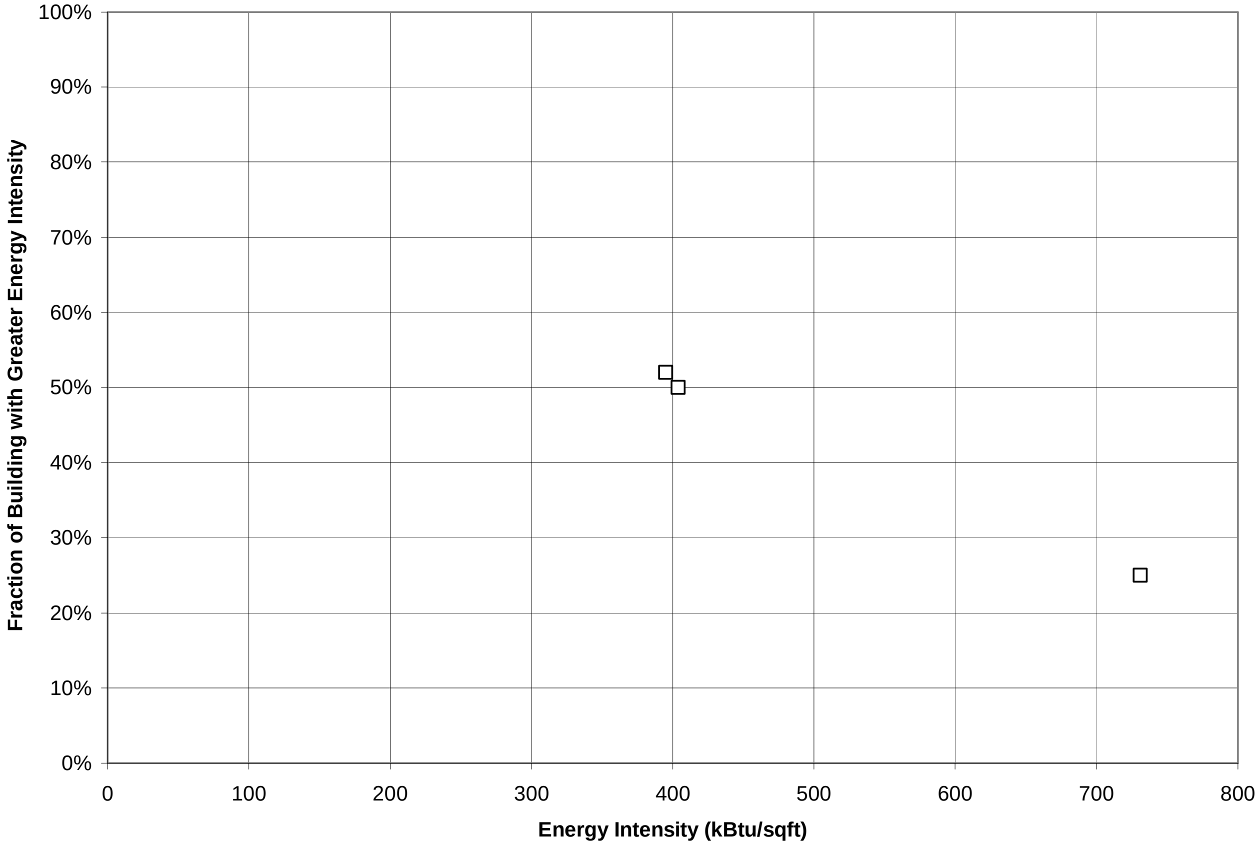
The zero energy building is represented by the y-intercept value of nearly 100%. Each rating was comparing the rated building with 13 to 21 buildings in the Arch database, with an average of 17 buildings.

Figure 41 – Supplementary SchoolsRatings in Arch



For hospitals, see Figure 42, the supplemental database only contains three buildings so few conclusions can be drawn especially with two of the points so close although the general trend of a better rating with lower energy intensity is as expected.

Figure 42 – Supplementary Hospitals Ratings in Arch

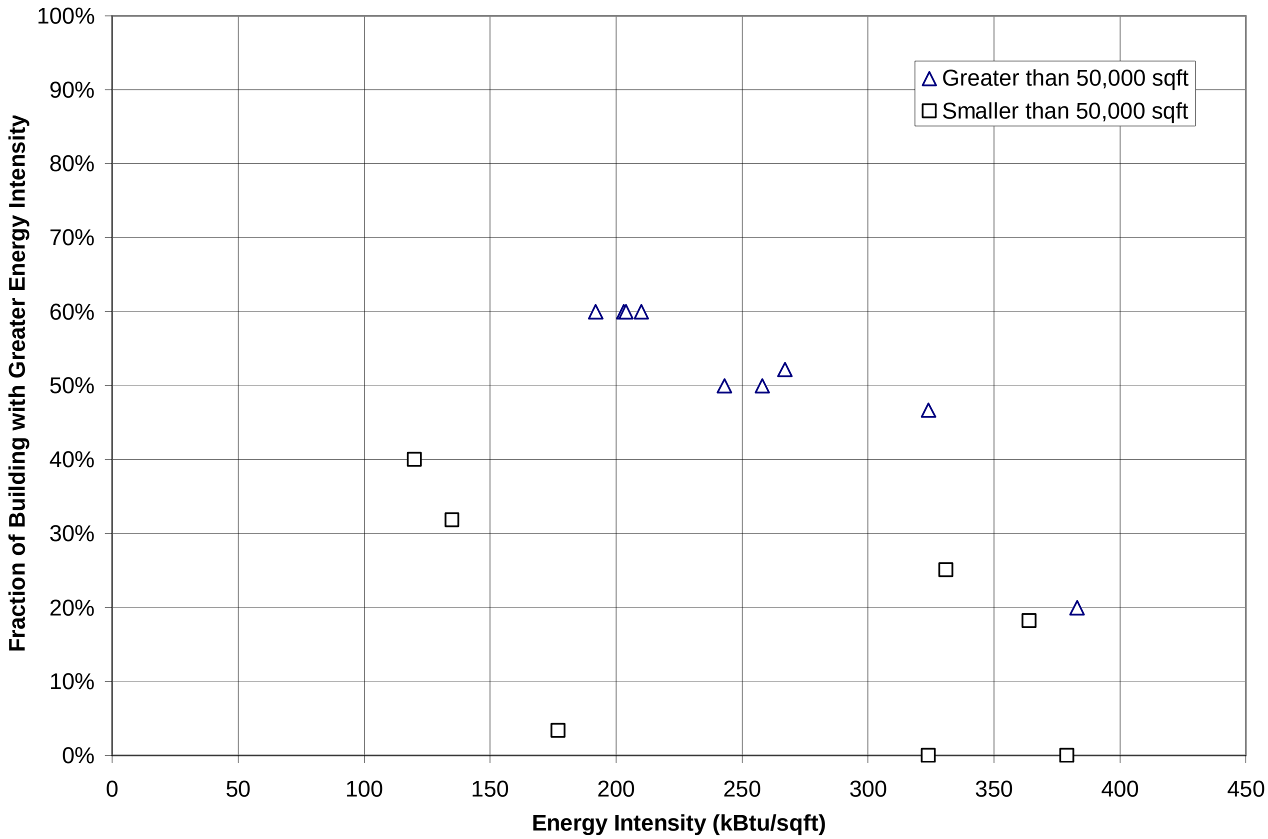


The sixteen hotel/motel buildings shown in Figure 43 show the general trend of lower rating at higher energy intensities. The data appears to be in two distinct groups based on floor area. The smaller buildings under 50,000 sqft correspond to smaller hotels or motels, typically three stories or less. The larger buildings may be thought of as high-rise “convention” style hotels. Higher ratings for the same energy intensity for the larger buildings may be due to the trend that larger hotels typically have additional energy use for meeting rooms and more food service areas. The linear regression model for the nine large hotels over 50,000 sqft is:

$$y = -0.001877x + 0.986172$$

This has a R^2 of 0.88. The smaller hotels include three that have ratings of 0% or nearly 0%. These seem like outliers and leave only four hotels, not enough for a meaningful regression model.

Figure 43 – Ratings for Supplemental Hotels/Motels in Arch

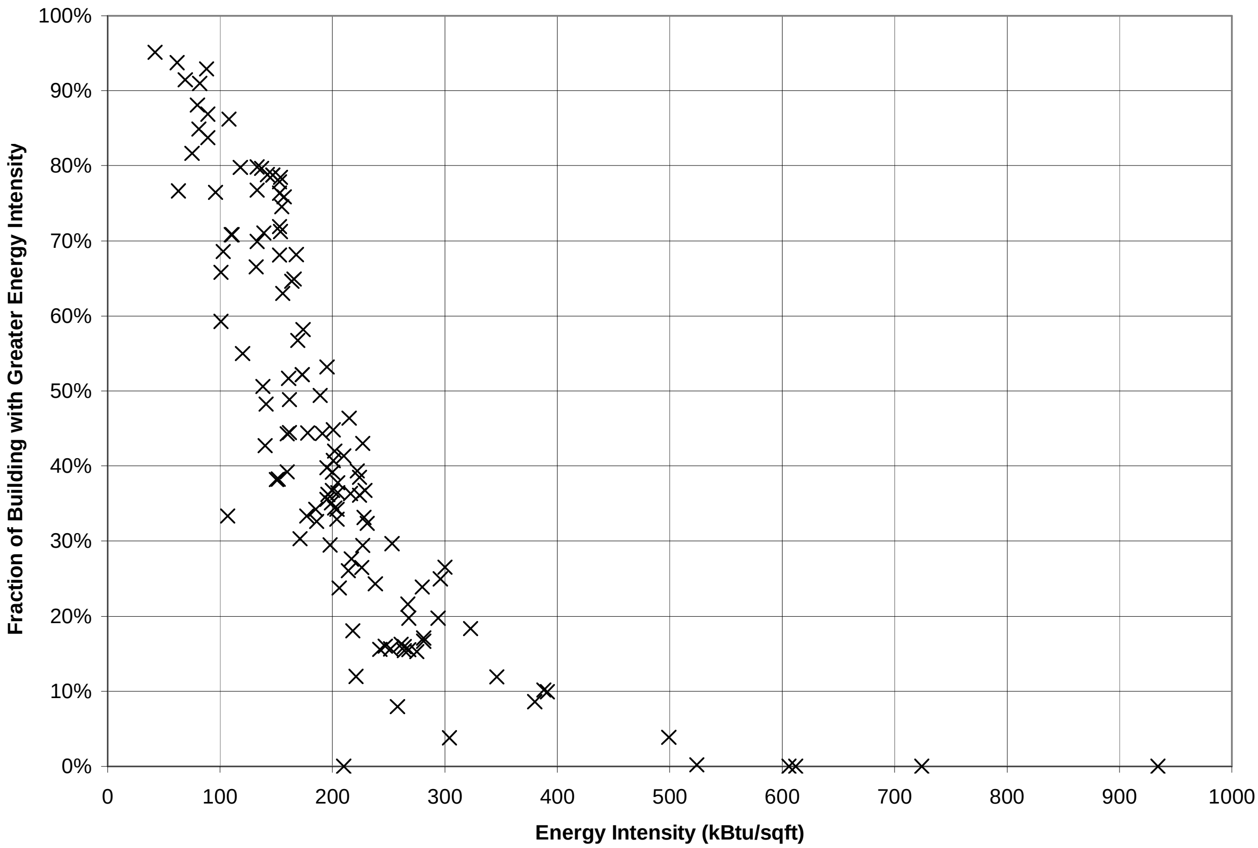


Office buildings account for the largest number of buildings in the supplemental building database with 127 of the 167 buildings, and are shown in Figure 44. After eliminating the few buildings that are at 0%, resulting ratings fit both a linear and quadratic correlation well. The complexity of the quadratic model may not be justified for the small increase in R^2 value from 0.75 to 0.78. The linear model is:

$$y = -0.003012x + 1.019651$$

Similar to other buildings, the y-intercept, which corresponds to a zero-energy building, is approximately 100%.

Figure 44 – Supplemental Office Buildings Rated in Arch



5.7 Discussion

The following conclusions may be drawn from the rating analysis performed using Arch and Cal-Arch on the 29 primary buildings:

- For Arch, the average rating was 69% with a range from 36% to 100%. Hospitals had the narrowest range of ratings followed by offices and schools.
- Rating the buildings using Cal-Arch resulted in an average rating of 47% with a range from 27% to 84%.
- When entering no ZIP code in Arch so the building is compared to all buildings nationally, the results can be very different from when a ZIP code is used.

- When hot and cold climates were compared with Arch, the change in rating was 23% for hospitals, 28% for schools and 41% for offices.
- When rating the buildings in the four different climate regions used in California for Cal-Arch the spread of ratings and the rank order of regions was inconsistent.
- Rating the buildings in Arch with 15% more and 15% less energy showed a wide range of rating changes from nearly none to almost 60%. Repeating this with Cal-Arch resulted in smaller changes on average of 17% for hospitals, 15% for offices and 23% for schools.
- Rating in Arch using site energy instead of source energy resulted in higher ratings for 22 of the 29 buildings. In Cal-Arch the ratings were not consistently higher or lower.
- When using the same energy intensity but a different total area, the ratings on average did not change very much with Cal-Arch but changed much more with Arch. This is because the change of area in Arch changes the selection of buildings being compared to the rated building. This is further demonstrated by turning on “filter by area” in Cal-Arch that results in some changes in the building ratings of 30%.

The following conclusions may be drawn from the analysis of the 167 supplementary buildings with Arch:

- Rating schools in Arch resulted in a strong linear relationship between the rating and the energy intensity.
- The lodging buildings seemed to be grouped by size. The ratings of the larger hotels had a strong linear relationship with energy intensity. The smaller hotels rated consistently lower for the same energy intensities.
- The office buildings rated using Arch showed a good fit to a linear regression model but became less linear at higher energy intensities.

One of the strengths of Arch and Cal-Arch is the single page of inputs that are easy for a building owner/operator to gather and enter. One disadvantage present in the input for Cal-Arch is the input for “whole buildings” which is confusing and unnecessary for most people who are only interested in whole building comparisons. For this analysis, it would have been useful if there had been a method of putting in a large number of buildings and downloading all of the results. This type of batch requirement might also be needed by people that manage a number of facilities such as a property manager.

The comparison to actual existing buildings is an easy concept for people to understand but the display of the building on a histogram is a perspective that would confuse many non-technical people. This is exasperated in Cal-Arch when three histograms are displayed. For the target user of a benchmarking system, this provides too much information. The values shown with Cal-Arch include quartiles that are not commonly used outside of engineering and science. When not all the graphs are shown because of a lack of data it is even more confusing.

For output, a simple number is probably a better approach with links for advanced users to display graphs. While Cal-Arch does have a number that may be used, the whole building energy “which is higher than X%” it is a low number in better buildings and a high numbers in worse buildings. This is the opposite of what many prospective users would expect who would associate 100% as a perfect test score. While buildings being rated in Arch or Cal-Arch, which appear near buildings with the highest energy intensities, clearly could be improved, it is not clear whether investment to improve buildings that fall in the middle of the distribution makes sense.

In addition, when not enough buildings are present in the database for the comparison to be valid, displaying the histogram with just a few buildings could easily be misinterpreted. The step changes of being better or worse than one building start becoming significant even though they should not be. Instead, either a warning should be displayed without a rating or the histogram or the selection should be automatically broadened to include more buildings and a warning displayed describing this along with the results and histogram.

If a building being rated has energy use that is not electricity or natural gas and is reported as “other” it does not get displayed on any graph. This proved to be confusing with buildings on a district steam system.

Arch uses the CBECS database as the source of most buildings and additional buildings are specifically described. By basing the rating method on a public database, experts assessing the benchmarking method assign greater confidence and understand any biases that may exist. Cal-Arch relies on the old CEUS dataset, which is not a public database. No one but the utility companies and a few select other parties have seen the data. The biases present due to using CEUS are difficult to assess. In addition, it is more difficult for experts to recommend a rating method that uses a non-public dataset since they cannot investigate the results thoroughly.

6 LEED-NC/LEED-EB

6.1 Overview

The U.S. Green Building Council (www.usgbc.org) publishes several different variations of Leadership in Energy and Environmental Design (LEED), including:

- New commercial construction and major renovation projects (LEED-NC)
- Existing building operations (LEED-EB)
- Commercial interiors projects (LEED-CI)

In addition, several types of LEED are in development:

- Core and shell projects (LEED-CS)
- Homes (LEED-H)
- Neighborhood Development (LEED-ND)

In all cases, the LEED rating is based on a point system where points are earned in several different areas related to sustainable design. To qualify, several prerequisites must be met and then additional credits earned. The focus of this project will be LEED-NC (USGBC 2002) and LEED-EB (USGBC 2004b). LEED-NC has been revised and the current version is 2.1. At the time of this research (December 2004) a draft of version 2.2 is out for public comment. LEED-EB has just completed its pilot phase and Version 2.0 was released in October 2004.

The credits under both LEED-NC and LEED-EB are grouped into:

- Sustainable sites
- Water efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation

The Energy and Atmosphere prerequisites and credits for LEED-NC for new construction are:

- Prerequisite 1 Fundamental Building Systems Commissioning
- Prerequisite 2 Minimum Energy Performance
- Prerequisite 3 CFC Reduction in HVAC&R Equipment
- Credit 1 Optimize Energy Performance
- Credit 2 Renewable Energy
- Credit 3 Additional Commissioning
- Credit 4 Ozone Depletion
- Credit 5 Measurement & Verification
- Credit 6 Green Power

The Energy and Atmosphere prerequisites and credits for LEED-EB for existing buildings are:

- Prerequisite 1 Existing Building Commissioning
- Prerequisite 2 Minimum Energy Performance
- Prerequisite 3 Ozone Protection
- Credit 1 Optimize Energy Performance
- Credit 2.1 – 2.4 Documenting Sustainable Building Cost Impacts
- Credit 3.1 Building Operations and Maintenance: Staff Education
- Credit 3.2 Building Operations and Maintenance: Building Systems Maintenance

- Credit 3.3 Building Operations and Maintenance: Building Systems Monitoring
- Credit 4 Additional Ozone Protection
- Credit 5.1 – 5.3 Performance Measurement: Enhanced Metering
- Credit 5.4 Performance Measurement: Emission Reduction Reporting
- Credit 6 On-site and Off-site Renewable Energy

For both LEED-NC and LEED-EB the Energy and Atmosphere Credit 1 (EA Credit 1) “Optimize Energy Performance” is the closest individual credit that, by itself, is an energy benchmark. For the case of LEED-NC, EA Credit 1 uses ASHRAE 90.1-1999 as the baseline and the Energy Cost Budget method, which uses building simulation, to determine how much above that baseline the building is. For LEED-EB, EA Credit 1 uses the ENERGY STAR for Buildings benchmark already described in this report.

Four different levels of certification may be granted for LEED-NC and LEED-EB as shown in Table 34.

Table 34 - LEED Levels and Points Needed

Level	*Points for LEED-NC*	*Points for LEED-EB*
Certified	26 to 32	32 to 39
Silver	33 to 38	40 to 47
Gold	39 to 51	48 to 63
Platinum	52 to 69	63 to 85

It is extremely unlikely for a building to achieve all of the points since some of the credits only apply to certain types of sites that are mutually exclusive.

At the time of this report, the LEED-NC 2.2 draft is out for public review. The major change to the document that is relevant to this report is the use of ASRHAE Standard 90.1-2004 instead of 90.1-1999. In addition, one of the most important credits currently references the Energy Cost Budget Method section of 90.1-1999 and is proposed to reference the Performance Rating Method section of 90.1-2004 which was expressly designed for use in determining building energy performance that exceeds code compliance.

One important point is that the LEED-NC 2.1 reference to ASHRAE 90.1-1999 Energy Cost Budget method includes many details about how the calculations are performed. Specifically, the savings are calculated based on the change in “regulated” energy consumption. Since plug-loads and process loads are not considered “regulated”, the percent savings calculated from LEED usually exaggerates the actual savings of the building.

6.1.1 Types of buildings

Any type of commercial or institutional building may qualify for LEED-NC or LEED-EB. Some of the credits are most likely to be taken by office buildings. Any commercial building can be evaluated by the Energy Cost Budget method of ASHRAE 90.1-1999 that LEED-NC references for EA Credit 1. For LEED-EB, any building can claim EA Credit 1 but if it is not the type of building that can be assessed using ENERGY STAR Label for Buildings, then sufficient documentation showing an equivalent ENERGY STAR score and the calculation steps need to be provided. The ENERGY STAR Label for Buildings can be used for:

- Offices (general offices, financial centers, bank branches, and courthouses)
- K-12 Schools
- Supermarkets/Grocery Stores
- Hospitals (Acute Care and Children's)
- Hotels/Motels
- Residence Halls/Dormitories
- Warehouses (refrigerated and non-refrigerated)

- Medical Offices

LEED-NC 2.1 defines the "square footage of the building" as "the total area in square feet for all rooms, including corridors, elevators, stairwells and shaft spaces."

Buildings with or without air conditioning may be evaluated using LEED-NC and LEED-EB. For LEED-NC, the Energy Cost Budget method of ASHRAE 90.1-1999 would compare the energy cost of the proposed building with a baseline building with air conditioning possibly creating a credit for a building without air conditioning that still maintained comfort.

6.1.2 Location

The U.S. Green Building Council promulgates the LEED rating systems without specific restrictions on locations. The intention is to at least serve a U.S. audience with the LEED rating system but it could be used in other locations as well. Certification for buildings outside the U.S. has been granted by USGBC and, theoretically, local organizations in other countries could adopt the LEED methodology and become a certifying organization.

LEED-NC reliance on the ASHRAE Standard 90.1 Energy Cost Budget method does not limit its use since it was designed to be usable internationally. Any typical weather files may be used with LEED-NC, according to section 11.2.2 (ASHRAE 1999b):

> *The simulation program shall perform the simulation using hourly values of climate data, such as temperature and humidity from representative climate data, for the city in which the proposed design is to be located. For cities or urban regions with several climate data entries, and for locations where weather data is not available, the designer shall select available weather data that best represents the climate at the construction site. Such selected weather data shall be approved by the authority having jurisdiction.*

Theoretically, variation in climate data due to microclimate effects could be incorporated in the weather files used in the simulation. No specific allowance for adjusting climate data is described.

Ten non-U.S. countries have either certified or registered projects under LEED (USGBC 2004)

- Canada
- China
- India
- Curacao
- Japan
- Spain
- Mexico
- Italy
- Cote d'Ivoire (formerly the Ivory Coast)
- Guatemala

It is not clear how the variation in local codes affected these projects.

For LEED-EB, the use of ENERGY STAR Label for Buildings means that the ZIP code of the building location must be known and that implies a U.S. location. See more details on this topic in Section 4 of this report.

6.1.3 Qualifications

LEED-NC includes several prerequisites in the Energy and Atmosphere area:

- Fundamental building systems commissioning
- Minimum energy performance
- CFC reduction in HVAC&R equipment

In addition, LEED-NC includes prerequisites in other areas which include:

- Erosion and sedimentation control
- Storage and collection of recyclables
- Minimum IAQ performance
- Environmental tobacco smoke control

The minimum energy performance requirement references ASHRAE Standard 90.1-1999 and states that the building needs to comply with that code or the local energy code, whichever is more stringent. The minimum IAQ performance requirement references ASHRAE Standard 62-1999 plus addenda.

For LEED-EB (USGBC 2004b), the Energy and Atmosphere prerequisites are very similar:

- Existing building commissioning
- Minimum energy performance
- Ozone protection

In this case, the Minimum energy performance is using ENERGY STAR Label for Building and a score of 60 for covered buildings. For buildings not covered by ENERGY STAR Label, details will appear in the LEED-EB Reference Guide when published.

Other prerequisites for LEED-EB from other areas of the system are:

- Erosion and sedimentation control
- Age of building
- Minimum water efficiency
- Discharge water compliance
- Source reduction and waste management
- Toxic material source reduction
- Outside air introduction and exhaust systems
- Environmental tobacco smoke control
- Asbestos removal or encapsulation
- PCB removal

Projects trying to qualify for LEED go through a multiple step process:

- Registration
- Application preparation
- Credit interpretation
- Application submittal
- Administrative approval
- Preliminary review
- Resubmittal
- Second preliminary review
- Final review
- Award
- Appeal

The building is registered with USGBC and the designers gain access to using the letter template and to the database of previous credit interpretations. The letter template is a spreadsheet that helps organize the information needed for the application submittal and helps guide the design team through the process of documenting the points being sought. Once registered, the design team can submit two credit interpretation requests if the current credit interpretations do not help understand the way a credit applies to their design. The building design can be registered at any time but it is best if done as early as possible in the design process. The application is submitted, usually in the form of a binder, to USGBC and is scanned initially to make sure all documents needed are present. Within 30 days after that, the preliminary review, usually conducted by a contractor to USGBC, reviews the information submitted and approves, denies or flags for audit each point being sought. Up to six credits or prerequisites may be selected for an audit that requires the design team to provide further substantiation within 30 days. Once the substantiation is submitted, a second review may require further substantiation of another two credits or prerequisites prior to the final review which takes three weeks. Finally, the design team has 30 days to accept the award for the certification level granted during the final review or appeal. An appeal can take an additional 30 days.

The entire process relies on the application and other documentation provided by the design team. No site visit by USGBC is included. The benefits of certification include a plaque for the building, possible financial incentives by state or local government, fulfilling a local government requirement, and publicity for the building, for LEED-NC, and for the design team.

6.1.4 Audience

The audience for LEED-NC includes:

- Architects
- Engineers
- Interior designers
- Lighting designer
- Facility managers
- Green building consultants
- Landscape architects
- Building owners
- Contracts
- Construction managers

The impetus for seeking certification is usually the building owner since the cost of submitting the application is borne by the owner. Usually the lead for the design team, the architect, is in the role of steering the project toward achieving certification. Depending on the points sought, different members of the design team may need to provide documentation. For the energy credit related to doing better than Standard 90.1, two detailed building simulation models need to be prepared. A large number of details is necessary to prepare such a model and members of the design team would provide that level of detail.

For LEED-EB, many of the same roles will be involved but clearly, the role of the facility manager becomes more prominent. Since ENERGY STAR Label for Buildings is used for one of the main energy credits, the data needed to support that is required.

Under LEED-NC and LEED-EB one point is given if a LEED accredited professional is part of the team that submits the application. A LEED accredited professional is someone who passes a standardized test on the details of LEED.

6.1.5 Ease of Use

LEED accredited professionals work with the building owner and design team on LEED-NC and the building operators on LEED-EB to complete the checklist of points. The building owner decides to seek certification for the building and hires a team to provide the paperwork to USGBC. From that perspective, the “ease of use” for the building owner is good. From the perspective of the design or operating teams, significant work must be performed to submit an application and support it through the certification. The letter template, a spreadsheet with tabs for each credit, provide a straightforward method to submit the application. While the application process could be further streamlined in LEED, in its current form the gathering and providing documentation for each credit should be relatively easy for each professional involved. In many cases, submittals require a few calculations that are embodied in the letter template. Overall, the process could take several weeks of effort to complete usually over a year or more of time between registering the project and certification.

The ultimate result of using LEED-NC is a building that may be described as certified, silver, gold or platinum. A plaque for the building will state the certification level and the USGBC web site will also reference the building (with the building owners permission).

The Reference Guide (USGBC 2003) includes guidance and ideas on how to achieve every credit in the LEED-NC protocol.

The most important energy related credit, the Energy and Atmosphere Credit 1, relies on exceeding ASHRAE Standard 90.1 using Section 11, the Energy Cost Budget (ECB) Method. This method relies on building energy simulation modeling which is often complex with many assumptions that need to be made. The ASHRAE document is supplemented by the LEED Energy Modeling Protocol described in the USGBC Reference Guide. The data required includes the details of the form of the building, the wall constructions, window descriptions, air and water distribution systems, and packaged and central plant heating and cooling systems.

6.1.6 Use Statistics

As of December 2004, according to the USGBC web site:

- 154 total certified projects
- 1738 total registered projects
- 211,634,906 gross square feet of projects (conservative)
- 50 states have registered projects
- 40 states have certified projects
- 13 countries have registered projects
- On average, 122,000 gross square feet per project

In addition, the number of projects by the type of building is shown in Table 35.

Table 35 – LEED Registered Projects by Building Type

Building Type	*# Registered Projects*	*Gross Square Feet*
Commercial Office	445	63,612,436
Higher Education	246	22,562,883
K-12 Education	161	18,988,038
Laboratory	147	22,397,298
Interpretive Center (museum, visitor center, zoo)	136	5,116,928
Multi-Unit Residential (apartments, dormitories)	136	19,309,973
Assembly (conv. center, place of worship, theater)	134	15,762,562
Library	112	9,039,086
Industrial (manufacturing, warehouse, pub. works)	111	12,040,714
Campus (corporate campus, school)	108	16,410,159
Other	104	11,461,008
Retail (store, supermarket, art gallery)	103	13,764,149
Public Order & Safety (police, jail, courthouse)	103	11,837,454
Recreation	84	6,951,710
Restaurant	69	10,488,126
Health Care	55	17,154,678
Park (greenway, recreation space, wildlife)	41	4,449,577
Daycare	38	3,421,352
Financial & Communications (bank, post office, data center)	36	5,058,778
Community (neighborhood, residential development)	25	1,994,540
Military Base	24	1,671,354
Transportation (airport, train station, bus station)	23	3,525,751
Animal Care (veterinary, kennel)	18	1,333,115
Hotel/Resort	17	1,493,970
Special Needs Housing (assisted living, long-term care)	13	920,739
Stadium/Arena	10	3,765,762
Single-Family Residential	8	638,109

Interestingly, the number of for-profit companies with LEED projects is now the largest single group based on ownership, see Table 36.

Table 36 – LEED Projects Based on Ownership

Type	*# Registered Projects*	*Gross Square Feet*
Profit Corporation	443	70,074,843
Local Government	417	38,448,431
Nonprofit Corporation	338	30,468,142
State Government	209	28,757,783
Federal Government	163	23,719,639
Other	146	18,599,543
Individual	19	1,099,165

To see the breakdown geographically, not including international locations, see the following table, Table 37.

Table 37 – LEED Projects Based on Location (US Only)

State	# Registered Projects	% Registered Projects	Gross Square Feet
CA	273	15.71	30,667,768
PA	105	6.04	11,138,620
WA	94	5.41	10,941,658
NY	89	5.12	15,465,292
OR	86	4.95	7,962,098
MA	70	4.03	9,164,010
TX	67	3.86	8,244,439
IL	67	3.86	10,742,965
MI	64	3.68	9,969,091
VA	58	3.34	6,082,758
AZ	48	2.76	4,689,930
GA	48	2.76	4,253,768
OH	45	2.59	5,704,723
MD	41	2.36	6,343,946
NJ	38	2.19	5,488,185
NC	36	2.07	4,033,181
CO	35	2.01	5,930,306
FL	32	1.84	2,422,970
MO	29	1.67	3,143,305
SC	20	1.15	1,659,863
VT	20	1.15	1,846,541
UT	18	1.04	1,347,641
WI	18	1.04	1,833,765
DC	17	0.98	6,883,746
CT	16	0.92	1,778,383
NH	16	0.92	1,339,096
ME	15	0.86	643,051
IA	14	0.81	1,102,245
NM	14	0.81	805,551
NV	13	0.75	1,415,213
AR	11	0.63	602,086
MN	11	0.63	1,450,085
IN	11	0.63	1,347,133
TN	10	0.58	859,853
AL	9	0.52	757,586
HI	8	0.46	597,125
ID	7	0.40	907,541
RI	6	0.35	359,139
NE	6	0.35	370,366
KS	6	0.35	594,123
MT	6	0.35	160,157
AK	5	0.29	66,289
MS	5	0.29	513,020
KY	5	0.29	220,661
LA	4	0.23	176,202
WV	4	0.23	619,013
WY	4	0.23	96,711
OK	4	0.23	233,746
SD	3	0.17	143,254
DE	3	0.17	130,500
ND	2	0.12	205,000

The number of certified projects at the different levels of certification is shown in Table 38, below. Note that the bronze level was only part of the Version 1 of LEED.

Table 38 – LEED Certified Projects By Level

	certified	*bronze*	*silver*	*gold*	*platinum*	**total**
Version 1	10	6	9	12	5	42
Version 2	59	0	36	35	5	135
Total	69	6	45	47	10	177

Two projects received the highest number of points, 56 out of 69, in Version 2 of LEED-NC:

- CII-Sohrabji Godrej Green Business Centre – Hyderabad, India
- NRDC Southern California Office, Robert Redford Building – Santa Monica, California

Both buildings achieved 10 points in Energy and Atmosphere Credit 1 indicating at least 60% better performance than ASHRAE 90.1, assuming they were both new construction. The NRDC project scored 16 out of 17 points for all of the Energy and Atmosphere credits. Many buildings scored 26 points, the minimum necessary for certification.

6.1.7 History

The U.S. Green Building Council was formed in 1993 (USGBC 2003) with the original goal of creating a sustainability rating system through the American Society of Testing and Materials (BDC 2003). They examined UK's BREEAM and Canada's BEPAC (Building Environmental Performance Assessment Criteria), Austin Texas's Green Builder program, and concluded that creating a new system was the best option. The first draft for review of the new rating procedure was created by the fall of 1994. After revisions, the LEED Version 1.0 Pilot Program was made available in August 1998 that accepted 12 projects that were certified by March 2000. During this time, development of Version 2.0 started and went through a comment and review period finally being released in March 2000. LEED 2.1 was an administrative update to 2.0, keeping the same level of stringency, so it did not need to be balloted. The most significant change in LEED 2.1 was the incorporation of the letter template to facilitate an easier approval process. Recently, the draft of LEED 2.2 is out for public review. The latest version does change stringency so it will need to be balloted. The most significant change related to energy is the reference to ASHRAE Standard 90.1-2004 instead of 90.1-1999 and the use of Appendix G instead of Section 11 of that standard to show above code performance. The 90.1-1999 standard includes the Energy Cost Budget section that is the basis of comparison but was never intended to serve as anything but a tradeoff method. Appendix G in the 90.1-2004 version of the standard was designed explicitly for evaluating above code performance in buildings.

6.1.8 Rating Cost

The charges for using LEED-NC are shown below in Table 39. Registration fees should be paid at the time the owner decides that the intent is to produce a LEED certified building. Certification fees are paid when the application is submitted to obtain the certification.

Table 39 – LEED-NC Fees

	<75,000 sqft	*75,000 to 300,000 sqft*	*>300,000 sqft*
Member Registration	$750	$0.01/sqft	$3,000
Non-member Registration	$950	$0.0125/sqft	$3,750
Member Certification	$1,500	$0.02/sqft	$6,000
Non-member Certification	$1,875	$0.025/sqft	$7,500

To become a member of USGBC, professional firms are charged between $250 to $1,500 depending on their size (based on annual sales). Other specific fees for classes, tests, credit interpretations, and appeals are separate.

6.2 Technical Basis

6.2.1 Empirical Data

LEED-NC does not utilize the comparison of the building to any statistically derived measure for energy consumption. LEED-EB utilizes ENERGY STAR Label for Buildings for this function, which was previously described.

6.2.2 Use of ASHRAE standards

LEED references many other codes and standards in an effort to leverage the work done by other organizations. For LEED-NC, ASHRAE is mentioned 143 times throughout the reference guide (USGBC 2003). For LEED-EB, ASHRAE is mentioned 28 times in the Green Building Rating System document (USGBC 2004b) that includes minimal discussion of each credit. Additional references to ASHRAE would be expected to appear in the reference guide for existing buildings when it is published. Those times are described in the following paragraphs. The LEED-NC and LEED-EB discussion is mixed to allow contrast between similar sections. The order that they appear is in the order of the credits. The credit numbers shown below are based on the LEED numbers system.

Sustainable Sites

LEED-NC, Sustainable Sites, Credit 8, Light Pollution Reduction – ASHRAE Standard 90.1-1999 (ASHRAE 1999b) is referenced in the section on "Synergies and Tradeoffs" due to its exterior lighting requirements for buildings and states "Exterior lighting strategies are affected by the transportation program, as well by as the total area of developed space on the project site. In addition to energy efficiency, the exterior lighting system requires commissioning and measurement & verification. ASHRAE 90.1–1999 (see EA Credit 1) includes provisions for exterior facade lighting and addresses automatic lighting controls, control devices, minimum lamp efficacy and lighting power limits. The standard requires separate calculations for interior and exterior lighting loads and, thus, trade-offs between interior and exterior loads are not permitted."

Energy and Atmosphere

LEED-NC, Energy and Atmosphere, Prerequisite 1, Fundamental Building Systems Commissioning – ASHRAE Guideline 1-1996 titled "The HVAC Commissioning Process" (ASHRAE 1996) and Guideline 4 titled "Preparation of Operating and Maintenance Documentation for Building Systems" are referenced in the resources section of the discussion but are not part of the requirement.

LEED-NC, Energy and Atmosphere, Prerequisite 2, Minimum Energy Performance – ASHRAE Standard 90.1-1999 sets the minimum performance criteria "Design the building to comply with ASHRAE/IESNA Standard 90.1-1999 (without amendments) (ASHRAE 1999b) or the local energy code, whichever is more stringent." The submittal requirements state, "Provide a LEED Letter Template, signed by a licensed professional engineer or architect, stating that the building complies with ASHRAE/IESNA 90.1-1999 or local energy codes. If local energy codes were applied, demonstrate that the local code is equivalent to, or more stringent than, ASHRAE/IESNA 90.1-1999 (without amendments)."

LEED-NC, Energy and Atmosphere, Credit 1, Optimize Energy Performance – ASHRAE Standard 90.1-1999 (ASHRAE 1999b) is part of the requirements of this credit which serves as the most important energy performance criteria in LEED. The requirement states,

> *Reduce design energy cost compared to the energy cost budget for energy systems regulated by ASHRAE/IESNA Standard 90.1-1999 (without amendments), as demonstrated by a whole building simulation using the Energy Cost Budget Method described in Section 11 of the Standard.*
>
> *Regulated energy systems include HVAC (heating, cooling, fans and pumps), service hot water and interior lighting. Non-regulated systems include plug loads, exterior lighting,*

garage ventilation and elevators (vertical transportation). Two methods may be used to separate energy consumption for regulated systems. The energy consumption for each fuel may be prorated according to the fraction of energy used by regulated and non-regulated energy. Alternatively, separate meters (accounting) may be created in the energy simulation program for regulated and non-regulated energy uses. If an analysis has been made comparing the proposed design to local energy standards and a defensible equivalency (at minimum) to ASHRAE/IESNA Standard 90.1-1999 has been established, then the comparison against the local code may be used in lieu of the ASHRAE Standard. Project teams are encouraged to apply for innovation credits if the energy consumption of non-regulated systems is also reduced.

The number of points also varies for this credit from 1 point for 15% savings new construction (5% existing buildings) to 10 points for 60% savings in new construction (50% existing buildings). Given the importance and complexity of this credit, the references to Standard 90.1 appear throughout the discussion. In addition, a reference to the Handbook of Fundamentals (ASHRAE 2001b) appears as "Before using nameplate ratings for load calculations, refer to Chapter 29 of the 2001 ASHRAE Handbook of Fundamentals for recommended heat gain from typical computer equipment (Table 8) and other equipment (Tables 5-10). These loads should be modeled using reasonable assumptions and must be modeled identically in both the budget and proposed cases."

LEED-NC, Energy and Atmosphere, Credit 2, Renewable Energy – ASHRAE Standard 90.1-1999 is again referenced for this credit. The credit gives one point for 5% renewable, two points for 10% renewable and three points for 20% renewable energy use. It utilizes some of the procedures and calculations in the previous credit (Energy and Atmosphere Credit 1) to perform the estimate of the percent savings. For example, when it comes to what cost should be assumed for utilities three options are provided including, "The second option is to compute the energy cost using a proposed energy rate schedule, preferably approved by the local ASHRAE/IESNA 90.1–1999 adopting authority. In the absence of these approved rates, a third option is to follow the rates as shown in Table 4. This table is based on Table 11-K from ASHRAE/IESNA 90.1–1999 User's Manual, and the data published periodically in the document DOE/EIA-0380 (2000/03)."

LEED-NC, Energy and Atmosphere, Credit 6, Green Power – ASHRAE Standard 90.1-1999 (ASHRAE 1999b) is used in the calculations discussion which states, "For the purposes of this credit, the building's grid-supplied electricity use is defined as that which is used by the energy components regulated by ASHRAE/IESNA Standard 90.1-1999 (see EA Credit 1), less the amount supplied by on-site renewable energy (see EA Credit 2)."

Indoor Environmental Quality

LEED-NC, Indoor Environmental Quality, Prerequisite 1, Minimum IAQ Performance – ASHRAE Standard 62-1999 (ASHRAE 1999) is referenced directly as a requirement: "Meet the minimum requirements of voluntary consensus standard ASHRAE 62-1999, Ventilation for Acceptable Indoor Air Quality, and approved Addenda (see ASHRAE 62-2001, Appendix H, for a complete compilation of Addenda) using the Ventilation Rate Procedure."

LEED-EB, Indoor Environmental Quality, Prerequisite 1, Minimum IAQ Performance – ASHRAE Standard 62.1-2004 (ASHRAE 2004) and 62-1999 (ASHRAE 1999) are mentioned in the first of three requirements, "Modify or maintain existing building outside-air (OA) ventilation distribution system to supply at least the outdoor air ventilation rate required by ASHRAE 62.1-2004. (ASHRAE 62.1.1-2001 with all Addenda can be used until ASHRAE 62.1-2004 is published.) If this is not feasible due to the physical constraints of the existing ventilation system, modify or maintain the system to supply at least 10 cubic feet per minute (CFM) per person." In addition, these standards are again mentioned in a similar context in the submittal requirements.

LEED-NC, Indoor Environmental Quality, Prerequisite 2, Environmental Tobacco Smoke Control – ASHRAE Standard 129-1997 titled "Measuring Air Change Effectiveness" (ASHRAE 1997) is used as part of one of the two ways to meet the intent of "Prevent exposure of building occupants and systems to

Environmental Tobacco Smoke". The first way is to not allow smoking in the building or near doors or windows. The second method, which references Standard 129 directly in the requirement, requires a designated smoking room with a performance measure of 1% of the tracer gas concentration detectable in adjoining rooms. In addition, ASHRAE Standard 62-1999 is referenced in the discussion of this requirement concerning design approach strategies.

LEED-NC, Indoor Environmental Quality, Credit 1, Carbon Dioxide Monitoring – ASHRAE Standard 62-2001, Ventilation for Acceptable Indoor Air Quality (ASHRAE 2001) is referenced directly in the requirement that states "Install a permanent carbon dioxide (CO2) monitoring system that provides feedback on space ventilation performance in a form that affords operational adjustments. Refer to the CO2 differential for all types of occupancy in accordance with ASHRAE 62-2001, Appendix C." In addition, in the discussion of this credit, for design approach strategies, ASHRAE Standard 55-1992 (ASHRAE 1992) is referenced "Indoor CO2 concentrations must be compared to outdoor CO2 concentrations to determine the differential point at which ventilation rates should be adjusted. The differential CO2 level that activates ventilation within each space must be based on occupant activity level and the corresponding metabolic rate (MET) defined in ASHRAE Standard 55-1992, Table 4. MET is the rate of energy production of an individual, which varies depending on activity level."

LEED-EB, Indoor Environmental Quality, Credit 1, Outdoor Air Delivery Monitoring– ASHRAE Standard 62.1-2004 is again referenced as a requirement for densely occupied spaces, "Configure system capability to generate an alarm visible to the system operator if the CO2 concentration in any zone rises more than 15% above that corresponding to the minimum outdoor air rate required by ASHRAE Standard 62 (see IEQ Prerequisite 1). CO2 sensors may be used for demand-controlled ventilation provided the control strategy complies with ASHRAE Standard 62 (see IEQ Prerequisite 1), including maintaining the area-based component of the design ventilation rate." For naturally ventilated spaces, one of the requirements states, "Operable windows areas must meet the requirements of ASHRAE 62.1-2004, section 5.1. (ASHRAE 62.1-2001 with all Addenda can be used until ASHRAE 62.1-2004 is published.)"

LEED-NC, Indoor Environmental Quality, Credit 2, Ventilation Effectiveness – ASHRAE Standard 129-1997 titled "Measuring Air Change Effectiveness" (ASHRAE 1997) is part of the requirement which states "For mechanically ventilated buildings, design ventilation systems that result in an air change effectiveness (Eac) greater than or equal to 0.9 as determined by ASHRAE 129-1997. For naturally ventilated spaces demonstrate a distribution and laminar flow pattern that involves not less than 90% of the room or zone area in the direction of air flow for at least 95% of hours of occupancy." In addition, the ASHRAE 2001 Handbook of Fundamentals (ASHRAE 2001b) is also referenced as one of three submittal options "For mechanically ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design complies with the recommended design approaches in ASHRAE 2001 Fundamentals Handbook Chapter 32, Space Air Diffusion. Complete the table summarizing the air change effectiveness achieved for each zone (must be 0.9 or greater)." This credit also includes discussion regarding design approach strategies that references ASHRAE 62-1999 (ASHRAE 1999b) "The minimum values for ventilation air rates in a space are determined by ASHRAE 62-1999 as part of IEQ Prerequisite 1. IEQ Credit 2 enhances the minimum indoor air quality requirements by ensuring that superior ventilation is delivered to the building occupants."

LEED-EB, Indoor Environmental Quality, Credit 2, Increased Ventilation – ASHRAE Standard 62.1-2004 is again referenced prior to its release and so Standard 62-1999 with addenda is an allowed alternative for the following requirement concerning mechanically ventilated spaces, "Increase outdoor air ventilation rates to all occupied spaces by at least 30% above the minimum required by ASHRAE 62.1-2004. (ASHRAE 62.1-2001 with all Addenda can be used until ASHRAE 62.1-2004 is published.)" This is echoed in the submittals section.

LEED-NC, Indoor Environmental Quality, Credit 3.1, Construction IAQ Management Plan –ASHRAE Standard 52.2-1999 titled "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size" (ASHRAE 1999c) is directly part of two of the requirements. The first of these states "If air handlers must be used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 must be used at each return air grill, as determined by ASHRAE 52.2-1999." The second requirement for this credit that references ASHRAE states "Replace all filtration media immediately prior to occupancy. Filtration media shall have a Minimum Efficiency Reporting Value (MERV) of 13, as determined by ASHRAE 52.2-1999 for media installed at the end of construction."

LEED-EB, Indoor Environmental Quality, Credit 3, Construction IAQ Management Plan – ASHRAE 52.2-1999 (ASHRAE 1999c) is referenced in one of the five requirements regarding the management plan, "If air handlers must be used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 must be used at each return air grill, as determined by ASHRAE 52.2-1999." In addition, Standard 55 (ASHRAE 1992) and 62 (ASHRAE 2001) are mentioned in the section about removing contaminants present in the building after construction, "CO2 measurements are only required if the building is regularly occupied during the testing. The ventilation rate is the outdoor air requirement per person, and the CO2 measurement is the differential between indoor and outdoor conditions based on occupancy type as defined by ASHRAE 62-2001. The MET Rate is as defined in ASHRAE 55."

LEED-NC, Indoor Environmental Quality, Credit 6.2, Controllability of Systems – ASHRAE Standard 90.1 (which year is not indicated) is mentioned in the discussion of this credit which has the intent of "Provide a high level of thermal, ventilation and lighting system control by individual occupants or specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants." The section that mentions 90.1 is on how to identify perimeter and non-perimeter spaces. In addition, the discussion also mentions Standard 62–2001 (ASHRAE 2001) as a reference for occupancy densities that appear in Table 2 of that standard.

LEED-EB, Indoor Environmental Quality, Credit 6.2, Controllability of Systems: Temperature & Ventilation – ASHRAE Standard 62.1-2004 or 62-1999 are referenced directly in the requirement, "Provide individual temperature and ventilation controls for at least 50% of the building occupants, enabling adjustments to suit individual needs and preferences, or those of a group sharing a multi-occupant space or workgroup area. Operable windows may be used in lieu of individual controls for occupants in spaces near the windows (20 feet inside of and 10 feet to either side of the operable part of the window), and where the operable windows meet the requirements of ASHRAE 62.1-2004 paragraph 5.1. (ASHRAE 62.1-2001 with all Addenda can be used until ASHRAE 62.1-2004 is published)"

LEED-NC, Indoor Environmental Quality, Credit 7.1, Thermal Comfort – ASHRAE Standard 55-1992 Thermal Environmental Conditions for Human Occupancy (ASHRAE 1992) sets the requirement for mechanically ventilated buildings "Comply with ASHRAE Standard 55-1992, Addenda 1995, for thermal comfort standards including humidity control within established ranges per climate zone." This standard is also referenced as part of one of the submittal options. The resources section covering both Credit 7.1 and 7.2 (below) references several ASHRAE documents as resources: ASHRAE Guideline 1–1989: Guideline for the Commissioning of HVAC Systems (ASHRAE 1989); ASHRAE Standard 52–76: Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter (ASHRAE 1976); ASHRAE Standard 62–1989: Ventilation for Acceptable Indoor Air Quality (ASHRAE 1989b); ASHRAE Standard 111–1988: Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems (ASHRAE 1988). Many of these references appear out of date including Guideline-1, Standard 52, and Standard 62.

LEED-EB, Indoor Environmental Quality, Credit 7.1, Thermal Comfort: Compliance – ASHRAE Standard 55-2004 (ASHRAE 2004b) is referenced directly in the sole requirement which states, "Comply with ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy." A reference to Standard 55 is repeated in the section on submittals.

LEED-NC, Indoor Environmental Quality, Credit 7.2, Thermal Comfort Permanent Monitoring System – ASHRAE Standard 55-1992 is mentioned as part of the submittal requirements "Provide the LEED Letter Template, signed by the engineer or responsible party, declaring that a permanent temperature and humidity monitoring system will operate throughout all seasons to permit control of the building zones within the seasonal thermal comfort ranges defined in ASHRAE 55-1992, Addenda 1995."

LEED-EB, Indoor Environmental Quality, Credit 7.2, Thermal Comfort Permanent Monitoring System – ASHRAE Standard 55 is mentioned as part of the Potential Technologies and Strategies section, "Systematic monitoring may be implemented by annual validation of continued performance to the selected comfort criteria conducted per ASHRAE Standard 55, Section 7 Evaluation of the Thermal Environment."

6.2.3 Documentation available

The U.S. Green Building Council provides significant documentation on LEED-NC in the form of the Reference Guide (USGBC 2003) and the Technical Review (USGBC 2004). For the lodging section is the Application Guide for Lodging using the LEED Green Building Rating System (USGBC 2001). The LEED-EB reference guide was not available at the time of this report however, the document on the Rating System (USGBC 2004b) succinctly describes the requirements. In addition, prior credit interpretation requests are available from USGBC to the design team after registration of the building. This includes rulings on many different special cases regarding the credits.

In addition, given its widespread use, many technical papers and reports are available concerning LEED. The primary energy related credit (EA Credit 1) references ASHRAE Standard 90.1-1999 (ASHRAE 1999b) which is further described in the Standard 90.1-1999 User's Manual (ASHRAE 1999d).

6.2.4 Calculation details

The credits that relate most directly to energy are the Energy and Atmosphere credits, shown in Table 40. Each credit includes some calculation details that are described in the reference guide (USGBC 2004).

Table 40 – Calculation Summary for Energy and Atmosphere Credits for LEED-NC

Credit	*Name*	*Calculation Summary*
1	Optimize Energy Performance	Using ASHRAE Standard 90.1-1999 Energy Cost Budget method, estimate the percent savings for only those end-uses regulated by the 90.1 standard. The calculation involves the use of a detailed, probably hourly, building energy simulation program such as DOE-2, TRACE, HAP or EnergyPlus. Regulated end-uses include HVAC, service water heating and lighting. Unregulated energy use such as plug loads are not included. The reference guide (USGBC 2003) has the following equations: Equation 1: Energy Savings Calculation $\%savings = 100 \times \frac{ECB' - DEC''}{ECB'}$ Equation 2: Energy Cost Budget Calculation $ECB' = baseline \frac{regulated \cdot kWh}{Total \cdot kWh} \times kWh \cdot Cost + baseline \frac{regulated \cdot Therms}{Total \cdot Therms} \times Gas \cdot Cost + baseline \times Other \cdot Energy$ Equation 3: Design Energy Cost Calculation $DEC' = proposed \frac{regulated \cdot kWh}{Total \cdot kWh} \times kWh \cdot Cost + proposed \frac{regulated \cdot Therms}{Total \cdot Therms} \times Gas \cdot Cost + proposed \times Other \cdot Energy$ Equation 4: Design Energy Cost with Renewables $DEC'' = DEC' - REC'$ Where ECB is the energy cost budget, DEC is the design energy cost and REC is the renewable contribution This means that the savings are only based on the change in energy cost for the regulated loads and excludes non-regulated loads like plug-loads, computers and other process loads.
2	Renewable Energy	Using the base energy use for the building from Credit 1, calculate the amount of energy from renewable source as a fraction of the total design energy cost. In addition the renewable energy cost is deducted from the base energy cost.

Table 40 (continued)– Calculation Summary for Energy and Atmosphere Credits for LEED-NC

3	Additional Commissioning	The intent is to verify and ensure that the entire building is operated the way it was intended to operate. No calculations needed.
4	Ozone Depletion	No HCFCs or Halon gas allowed. No calculations needed.
5	Measurement and Verification	Install metering and have measurement and verification plan. No calculations for obtaining the credit but the plan must include how to compare the baseline energy, the predicted energy against the metered energy. Use metering and software models to estimate the baseline energy use and the energy use of the building as designed.
6	Green Power	Provide at least 50% of electricity from grid based renewable sources. Use the design energy use based on kWh from Credit 1 to determine the savings. On site renewables from Credit 2 reduce the design energy use.

From the above summary, one can see that three of the credits, 1, 2 and 6, of LEED-NC involve calculations that use the ASHRAE Standard 90.1-1999 (ASHRAE 1999b) Energy Cost Budget (ECB) Method which is further discussed in the 90.1 users manual (ASHRAE 1999d). The ECB Method is contained in Section 11 of 90.1-1999 that covers approximately seven pages. The Users Manual includes 45 pages, with examples, describing the ECB method. Instead of recreating that discussion here, the reader is advised to review those references. Some important points are:

- Based on building energy simulation software tools that include a large number of detailed inputs.
- A design model is first constructed and then a budget model is derived from it based on baseline levels of efficiency and practice.
- The building description would include locations of all walls, windows, roofs, floors, etc. often using a coordinate system.
- The ECB method is based on cost and actual utility rates are to be used. LEED-NC allows the use of state average commercial sector costs.
- While the ECB method is described in detail, the algorithms used in the individual building energy simulation programs may or may not be available to review.
- The many input details for a building energy simulation model mean that the impact of small errors on an individual input usually results in only a small change in the output making input data quality a smaller concern. This is especially true if the input does not change from the design and baseline simulation model.
- Factors such as occupant density and scheduled hours of operation directly affect the energy use model but both need to be kept the same in the design and budget simulations. Productivity of the occupants is outside the calculation although LEED-NC does have other credits for thermal comfort, daylight, and views that are known to affect productivity.
- Actual weather is not available since modeling is performed prior to construction, instead typical weather is used based on nearby weather station history.

- End-uses that are not regulated such as plug loads such as computer use will impact the savings based on the heat added to the space but is not included directly since LEED-NC is only concerned with regulated end-uses.
- The amount of outside air does affect the simulations but must be the same in both the energy budget and design building models.

For existing buildings, LEED-EB, also has several credits related to energy, see Table 41. The calculation summary is based on the rating system without use of a reference guide since it was not available at time of this report.

Table 41 – Calculation Summary for Energy and Atmosphere Credits for LEED-EB

Credit	*Name*	*Calculation Summary*
1	Optimize Energy Performance	Use ENERGY STAR Label for Buildings to perform benchmarking. Provide actual utility bills to support rating. For building types not addressed by ENERGY STAR, an alternative method will be provided in the upcoming reference guide to LEED-EB. See Section 2 of this report on ENERGY STAR Label for Buildings.
2.1 – 2.4	On-site and Off-site Renewable Energy	Divide the metered on-site renewable energy production by the total used by the building for on-site renewable points. For off-site show utility bills and certificates. One point for 5% on-site or 25% off-site renewable, two points for 10% onsite or 50% off-site, three points for 20% on-site or 75% off-site, four points for 30% on-site or 100% off-site.
3.1	Building O&M: Staff Education	At least 24 hours of education for building operating staff each year. No calculations required.
3.2	Building O&M: Building Systems Maintenance	Comprehensive best practice equipment preventative maintenance program. No calculation required.
3.3	Building O&M: Building Systems Monitoring	Monitoring system for conditions in building and space conditioning equipment. No calculations required.
4	Additional Ozone Protection	No HCFCs or Halon gas allowed. No calculations needed.
5.1 – 5.3	Performance Measurement: Enhanced Metering	Monitor energy and water consumption, cooling and heating loads, process consumption, etc. Calculate actual equipment efficiency.
5.4	Performance Measurement: Emission Reduction Reporting	Emission reduction reporting from third party certification program. Calculate percentages saved.
6	Documenting Sustainable Building Cost Impacts	Document ongoing costs for sustainable building. Calculate changes in operating costs.

6.2.5 Validation

Many of the credits in the Energy and Atmosphere sections of LEED-NC and LEED-EB cannot be validated. The credits in each that should be specifically validated are:

- LEED-NC EA Credit 1 – Optimize Energy Performance
- LEED-NC EA Credit 2 – Renewable Energy
- LEED-EB EA Credit 1 – Optimize Energy Performance
- LEED-EB EA Credit 2 – On-site and Off-site Renewable Energy

The LEED-EB Optimize Energy Performance credit relies on ENERGY STAR Label for Buildings that is described previously in the report. LEED-EB On-site and Off-site Renewable Energy implies that 25% off-site renewable energy that is certified by the Green-e seal by the Center for Resource Solutions is equivalent to 5% on-site renewable energy and that 30% on site is equivalent to 100% offsite. These comparisons seem arbitrary.

The two LEED-NC credits, Optimize Energy Performance and Renewable Energy both rely on ASHRAE Standard 90.1-1999 Energy Cost Budget Method. This method has not been validated but did go through an ANSI approved public review process.

Overall, some have questioned the validity of how points are assigned in LEED-NC. Some points have different levels of environmental impact and some points are employed more often, implying that they are easier to cost justify. One report by NIST titled Evaluation of LEED Using Life Cycle Assessment Methods (Scheuer 2002) found some specific issues with LEED-NC. Using a methodology consistent with ISO 14040 (ISO 1997) and focusing on Material & Resources and Energy & Atmosphere credits, each credit was assessed in terms of energy consumption and solid waste production. The report acknowledges that LEED-NC was not based on life cycle assessment methods but concludes:

> *This project revealed a variety of discrepancies in outcome in LEED credits. These discrepancies undermine the achievement of individual credit intentions and the goals of the program as a whole. Life Cycle Assessment has proven to be a valuable methodology for simulation of impacts from utilization of the LEED program. The lack of comparability between LEED ratings and LCA results indicates that when considered in a life cycle perspective LEED does not provide a consistent, organized structure for achievement of environmental goals. Further, the disaggregation into individual credits may stimulate specific solutions, but overall building integration may be less than ideal. Finally the lack of balanced results may lead to so much variation in total building environmental performance that a building's rating may not align with its actual performance. In these respects the LEED program does not fulfill its goal of providing a standard of measure. While LEED appears to be accomplishing the goals of an eco-labeling program that is as a marketing and policy tool it is not as successful at being a comprehensive methodology for assessment of environmental impacts. This is especially troubling from a consumer perspective, as the LEED rating is intended to become the "currency" of environmental value, upon which future users, owners, and public agencies rely. Refinement of LEED should emphasize integration of life cycle oriented measures and standards.*

Concerning LEED-NC Energy and Atmosphere Credit 1, Optimize Energy Performance, the report also states

> *The choice to exclude non-regulated loads may be based on industry practices, or complexities in approximating these loads, however their exclusion does inflate the currently defined LEED ESP, creating a gap between LEED ESP and actual savings in the current program format. If unregulated loads were included in the calculation, opportunities to reduce consumption in these loads could present themselves, however under the current format there is no incentive to reduce these loads.*

The USGBC has responded to this issue by using a scale for the draft LEED-NC 2.2 version that includes both regulated and unregulated loads.

The NIST report continues with concerns about ASHRAE Standard 90.1:

> *The use of a prescriptive energy standard that focuses on component selection and not the total performance of the building could lead to "gaming" the modeling process in order to achieve results, rather than rewarding the design of high performance buildings.*

The NIST report also finds an issue with the use of utility pricing as part of the 90.1 Energy Cost Budget method:

> *Another problematic aspect of the EA1 calculation is that changes in the price of a specific energy type alters that energy type's fractional contribution to ECB and DEC in a way that appears imbalanced. For example an increase in electric prices decreases the amount of electric reductions needed to achieve a given ESP, and correspondingly reduces the actual energy savings achieved. This calculation method creates inequities in demand reduction requirements for achieving EA1 depending on regional energy pricing. Additionally it creates a loophole where a LEED user would benefit from documenting the highest possible energy pricing to reduce their requirements, regardless of long-term price conditions.*

Electric Price \$/kWh	*%elec Reduction for 1 LEED pt*	*Life span GJ saved*
0.04	*21%*	*215,669*
0.07	*18%*	*184,859*
0.10	*16%*	*164,319*

Concerning LEED-NC Energy and Atmosphere Credit 2, Renewable Energy, the report states:

> *There are two factors in this calculation that are problematic. First the exclusion of unregulated loads (see the EA1 credit structure and calculations discussion sections), while perhaps practical, does reduce the percentage of building load met by the renewable energy system. In SWH regulated loads are 90% of the total load, so the fraction of regulated loads required to meet the target REP is lower than the fraction that would be needed to meet the total load. More importantly, the DEC" calculation leads to a lower actual contribution to achieve the desired target REP because DEC" deducts REC, reducing the denominator. For example, in SWH the DEC" for a 5% target REP is 95% of the DEC (it becomes a greater difference the greater the renewable contribution). These two factors combine to yield a total renewable contribution lower than the LEED credit amount, both in energy cost and energy contribution. It is understandable to base the calculations on cost of energy, since total cost is more relevant to building owners than percentage of energy being met, and there may be pragmatic reasons to exclude unregulated loads (difficulties in estimation being the most obvious reason). However, a motivation for the DEC" calculation is not apparent. DEC" is being defined as DEC minus the loads that the renewable energy is meeting, an approach that may be appropriate for determining ESP under EA1. However, calculating REP as REC over DEC" is double dipping, since the REC is already being accounted for by canceling out some of the DEC load. An extreme example highlights this issue. If the target REP is 100%, the DEC" calculation would require that the REC be half of DEC, thus a 100% REP = 50% DEC. In this case a building could claim, according to LEED, a 100% renewable energy contribution, but only actually be providing 50% of the Design Energy Cost.*

In another report focused on adopting a life cycle assessment approach to LEED (HORST 2003) the author again is recommending not using energy cost as a measure and instead:

> *A true performance measure would focus on the environmental impacts of concern, fossil fuel depletion, greenhouse gas emissions, solid waste production, etc. An interim energy reduction requirement could be designed to relate as closely as possible to those measures. As a first step, the requirements could focus on amounts of energy use by types, as opposed to energy costs. This will automatically eliminate other distortions that may arise from the use of cost as a yardstick.*

The relative impact of different credits based on first cost, operating cost and environmental impact has been questioned. One source (OFEE 2004) stated:

> *More generally, considering implementation costs and environmental benefits, some believe certain LEED credits are inappropriately weighted. For example, installing a vegetated roofing system is rewarded with a single credit, as is installing an outlet for electric vehicles or bike racks in the parking lot.*

Despite these specific criticisms, LEED in general has been embraced by a significant fraction of the design community in the United States. The technical underpinning is not necessarily the reason for its popularity but given the large number of people looking at the methodology, few glaring errors have been uncovered. This may be due in part by the fact that LEED was developed by committees, which include building design professionals. Furthermore, they have established a process, credit interpretation requests that provide a method for architects and engineers to include LEED in innovative designs.

The certification process for a building means that building designs are thoroughly reviewed to minimize the chance of erroneous assumptions. The current draft of LEED-NC 2.2 is open for public review as was the 2.0 version (the 2.1 version was an administrative update and not subject to public review).

6.2.6 Weight of Energy

The points assigned to different areas based on LEED-NC 2.1 and LEED-EB 2 are shown below in Table 42.

Table 42 – LEED Point Distribution

Category	*New Construction*	*Existing Buildings*
Sustainable Sites	14	14
Water Efficiency	5	5
Energy and Atmosphere	17	23
Materials and Resources	13	16
Indoor Environmental Quality	15	22
Innovation	5	5
Total	69	85
% Energy and Atmosphere	25%	27%

In both existing and new buildings, about a quarter of the available points are for the Energy and Atmosphere category. Different certification levels are available for LEED with point thresholds shown in Table 43, below.

Table 43 - LEED Levels and Points Needed

Level	*Points for LEED-NC*	*Points for LEED-EB*
Certified	26 to 32	32 to 39
Silver	33 to 38	40 to 47
Gold	39 to 51	48 to 63
Platinum	52 to 69	63 to 85

The number of points means that even for the lowest level, "Certified", more than one category needs to have points awarded. It is not enough to get all of the Energy and Atmosphere points since they only result in about 65% new construction and 72% existing building points needed.

Within the Energy and Atmosphere category are credits that have different point values shown on Table 44 and Table 45, below.

Table 44 – Points for Energy and Atmosphere Credits for LEED-NC

Credit	*Description*	*Maximum Points Possible*
1	Optimize Energy Performance	10
2.1-2.3	Renewable Energy	3
3	Additional Commissioning	1
4	Ozone Depletion	1
5	Measurement & Verification	1
6	Green Power	1

Table 45 – Points for Energy and Atmosphere Credits for LEED-EB

Credit	*Description*	*Maximum Points Possible*
1	Optimize Energy Performance	10
2.1 – 2.4	On-site and Off-site Renewable Energy	4
3.1	Building Operations and Maintenance: Staff Education	1
3.2	Building Operations and Maintenance: Building Systems Maintenance	1
3.3	Building Operations and Maintenance: Building Systems Monitoring	1
4	Additional Ozone Protection	1
5.1 – 5.3	Performance Measurement: Enhanced Metering	3
5.4	Performance Measurement: Emission Reduction Reporting	1
6	Documenting Sustainable Building Cost Impacts	1

While the number of points to Credit 1, Optimize Energy Performance, is ten for both LEED-NC and LEED-EB, the overall importance is reduced for LEED-EB. To achieve the certified level for both, the Credit 1 points represent 38% for LEED-NC and 31% for LEED-EB.

6.3 Application

Unlike ENERGY STAR for Buildings, ENERGYguide, Arch, or Cal-Arch, the rating systems LEED-EB and BREEAM have a broader scope. They are not just energy performance rating methods but are environmental rating methods which include energy but for LEED-EB also cover sustainable sites, water efficiency, material resources, and indoor air quality and for BREEAM Office management, health and wellbeing, transport, water and pollution. This section focuses on LEED-EB and the next will cover BREEAM.

The main input for LEED-EB is a spreadsheet based "Letter Template" that is completed and submitted to the US Green Building Council with supporting details. Each category has prerequisites and credits. The credits have point values usually between 1 and 3 points. The major energy performance credit can be up to 10 points. To achieve certification 32 points must be gained, with 40 for silver, 48 for gold and 64 for platinum out of a possible 85 points. The Energy and Atmosphere portion accounts for 23 of the 85 points, approximately 27% of the total points possible or 72% of the points needed for certification.

The Energy and Atmosphere prerequisites and credits for LEED-EB for existing buildings are shown below with the number of points available in for each shown in parentheses:

- Prerequisite 1 Existing Building Commissioning
- Prerequisite 2 Minimum Energy Performance
- Prerequisite 3 Ozone Protection
- Credit 1 Optimize Energy Performance (10)
- Credit 2 On-site and Off-site Renewable Energy (4)
- Credit 3.1 Building Operations and Maintenance: Staff Education (1)
- Credit 3.2 Building Operations and Maintenance: Building Systems Maintenance (1)
- Credit 3.3 Building Operations and Maintenance: Building Systems Monitoring (1)
- Credit 4 Additional Ozone Protection (1)
- Credit 5.1 – 5.3 Performance Measurement: Enhanced Metering (3)
- Credit 5.4 Performance Measurement: Emission Reduction Reporting (1)
- Credit 6 Documenting Sustainable Building Cost Impacts (1)

While a building receiving any of these credits is likely to have lower energy consumption than a building not receiving these credits, only Credit 1 Optimize Energy Performance is directly impacted by energy use and will be the only credit closely examined in this section. Both Prerequisite 2 Minimum Energy Performance and Credit 1 Optimize Energy Performance are based on EPA's ENERGY STAR for Buildings. The 10 possible points for Credit 1 represent 12% of the total points possible or 31% of the points needed for certification. The number of LEED-EB points that correspond to various ENERGY STAR ratings are shown below in Table 46.

Table 46 – ENERGY STAR Points Needed for LEED-EB

LEED-EB Points	ENERGY STAR Rating
Prerequisite	60
1	63
2	67
3	71
4	75
5	79
6	83
7	87
8	91
9	95
10	99

After the first point, to gain an additional point for LEED-EB, the ENERGY STAR rating needs to increase by 4. This decreases the impacts associated with the input sensitivity analysis discussed later. In addition, to earn the ENERGY STAR Label a rating of 75 is required which corresponds to 4 points for LEED-EB Energy and Atmosphere Credit 1. Points can be earned in LEED-EB for a building that could not earn the ENERGY STAR Label.

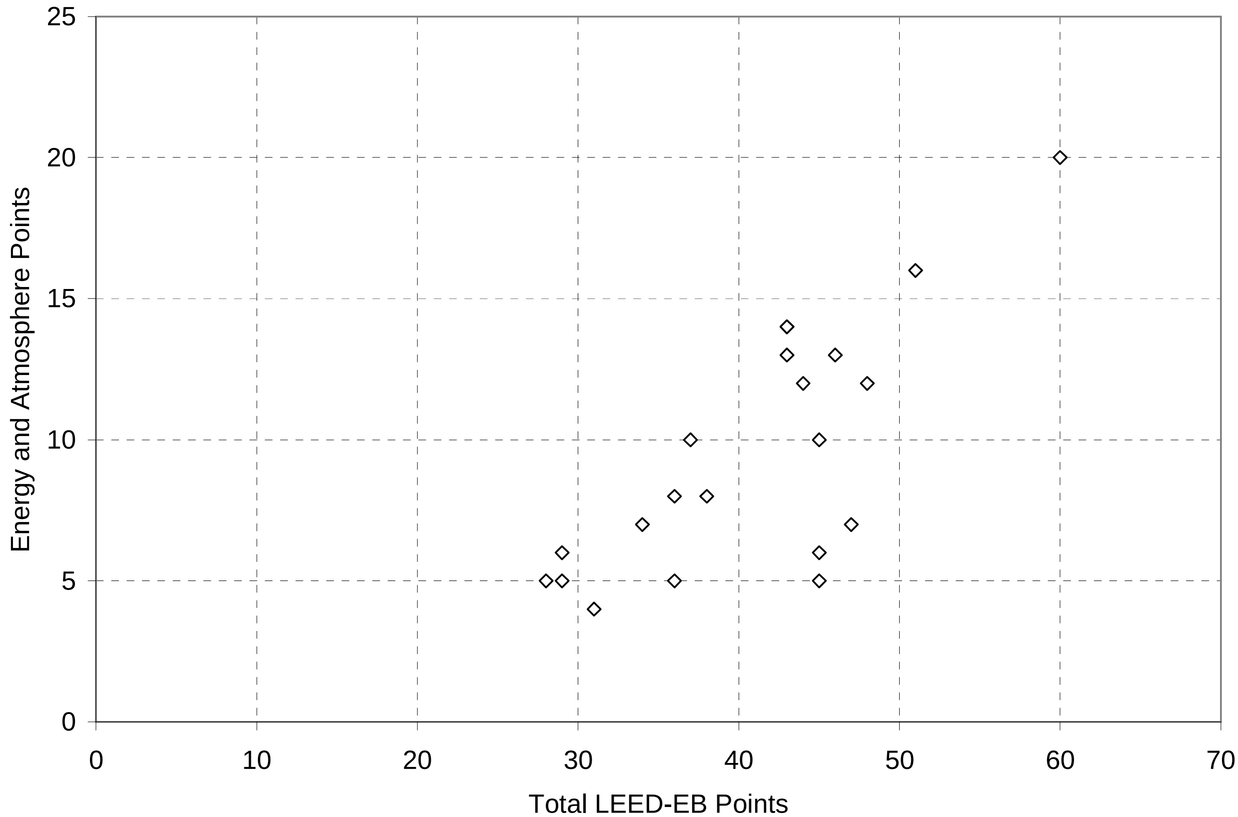
Table 47 shows the mapping of responses from the questionnaire to specific credits and prerequisites for LEED-EB.

Table 47 – LEED-EB Survey Question Mapping

Number	Credit	Questionnaire Item
Pre. 1	Existing Building Commissioning	Building operation plan developed and followed?
Pre. 2	Minimum Energy Performance	Calculated based on ENERGY STAR
Pre. 3	Ozone Protection	Are CFC refrigerants used in the building?
EA 1	Optimize Energy Performance	Calculated based on ENERGY STAR
EA 2	Renewable Energy	Percent of use is off-site (Green-e) renewable?
		Percent of use is on-site renewable
EA 3.1	Staff Education	24 hours of maintenance staff training annually
EA 3.2	Building Systems Maintenance	Preventative maintenance program
EA 3.3	Building Systems Monitoring	Performance monitoring of space conditioning equipment
EA 4	Additional Ozone Protection	Are HCFC or Halon used in the building?
		Refrigerant loss rate per year
EA 5.1-5.3	Enhanced Metering	Is lighting electric separately metered?
		Are plug or process electric separately metered?
EA 5.4	Emission Reduction Reporting	Track, record and report emission reduction efforts?
EA 6	Document Sustainable Building Cost Impacts	Document sustainable building cost impacts?

Based on public information from the USGBC web site, Figure 45 shows all the buildings that have a LEED-EB award and the number of Energy and Atmosphere points for each. The trend is to earn more Energy and Atmosphere points with increasing total points with an average of 23% of the total points being Energy and Atmosphere points.

Figure 45 – Energy and Atmosphere Points Compared to Total Points in LEED-EB



6.4 Baseline

The following table shows the baseline buildings and their estimated LEED-EB Energy and Atmosphere scores. Six of the buildings participated in the LEED-EB program and have been awarded a certified rating or higher. Two buildings were participants in the LEED-EB rating program but their certification sheets were not provided so they are not included in this analysis. The remaining buildings have not participated in LEED but have completed a questionnaire with questions related to each point in the Energy and Atmosphere section.

For the six buildings awarded with LEED-EB certified or higher, the ENERGY STAR rating was recomputed so it would be consistent with the rest of the ratings performed in the analysis and used the latest utility data possible. Of these six, three had no change to their ENERGY STAR rating, two went down two Energy and Atmosphere Credit 1 points and one went up one point.

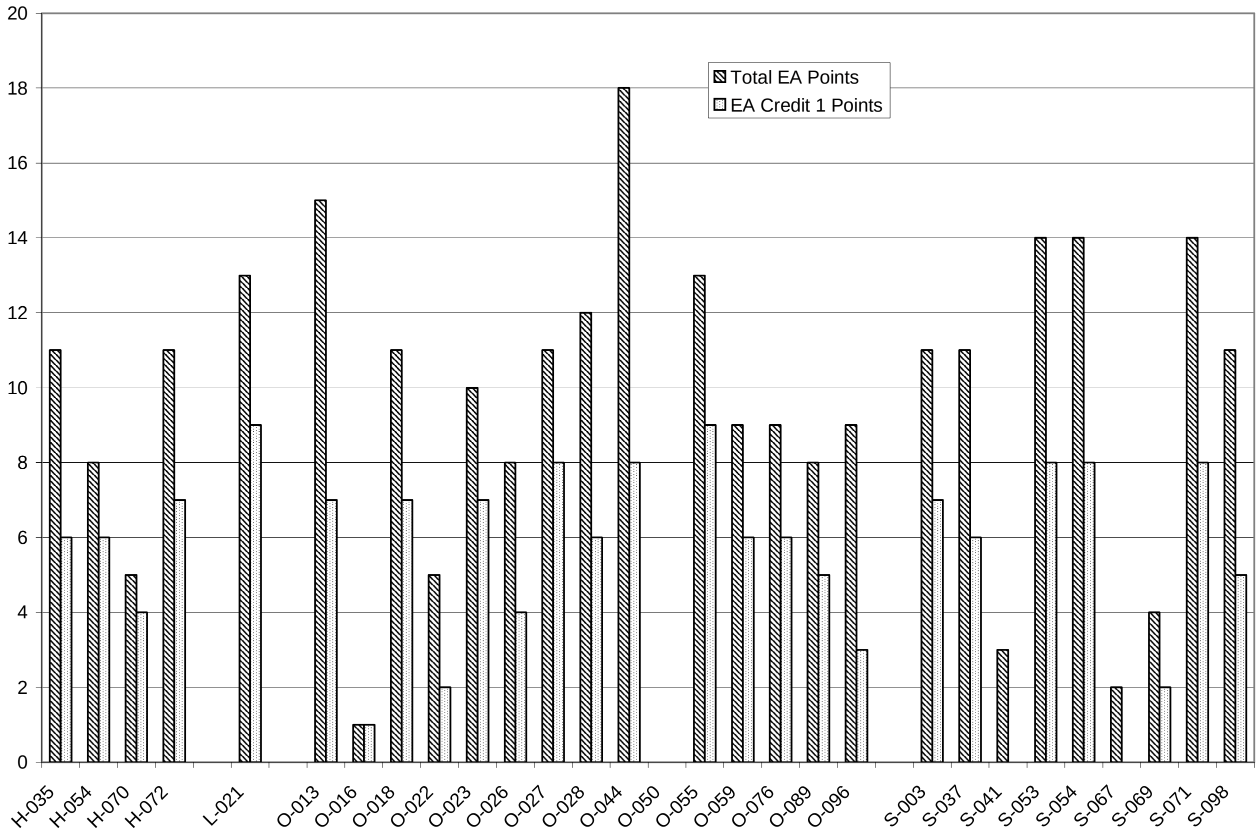
Table 48 shows the Energy and Atmosphere points for the primary buildings discussed throughout this report.

Table 48 – Energy and Atmosphere Points in LEED-EB

Building	Total EA Points	EA Credit 1 Points
H-035	11	6
H-054	8	6
H-070	5	4
H-072	11	7
L-021	13	9
O-013	15	7
O-016	1	1
O-018	11	7
O-022	5	2
O-023	10	7
O-026	8	4
O-027	11	8
O-028	12	6
O-044	18	8
O-050	0	0
O-055	13	9
O-059	9	6
O-076	9	6
O-089	8	5
O-096	9	3
S-003	11	7
S-037	11	6
S-041	3	0
S-053	14	8
S-054	14	8
S-067	2	0
S-069	4	2
S-071	14	8
S-098	11	5

The following figure, Figure 46, shows these values graphically.

Figure 46 – LEED-EB Energy and Atmosphere Points



6.5 Input Sensitivity

LEED-EB Energy and Atmosphere Credit 1 – Optimize Energy Performance is the only credit in LEED-EB that responds directly to energy use and is based on the ENERGY STAR rating method. The section on ENERGY STAR in this report describes that rating method. That discussion also applies to this credit. The only differences is that a change in four rating points for ENERGY STAR is required to change the LEED-EB rating by one point. This means that input sensitivity is attenuated. Rather than repeating the graphs that appear in the ENERGY STAR section of this report, the summary table below, Table 49, shows the affect of this attenuation for input changes common to all building types. In addition, due to the step nature of the changes, few conclusions may be drawn since the size of the step is similar to the changes in the number of LEED-EB points.

Table 49 – Impact of Input Changes on All Buildings for LEED-EB

Building	Cold Location	Hot Location	15% Energy Reduction	15% Energy Increase	15% Area Reduction
H-035	-1	0	2	-2	-2
H-054	0	2	2	-3	-2
H-070	-1	0	3	-4	-4
H-072	-2	-1	2	-3	-3
L-021	-1	-3	1	-2	0
O-013	-1	0	1	-3	-2
O-016	0	0	3	-1	-1
O-018	0	1	1	-1	0
O-022	1	2	3	-2	-2
O-023	-1	-1	1	-2	0
O-026	0	1	2	-2	-2
O-027	-1	0	1	-1	-1
O-028	0	0	1	-3	-2
O-044	1	1	1	0	0
O-050	0	0	4	0	0
O-055	0	0	0	-1	-1
O-059	-1	0	2	-2	0
O-076	-1	0	1	-3	-2
O-089	-3	-2	2	-4	-2
O-096	-2	-1	3	-3	-3
S-003	0	1	1	-2	-2
S-037	-2	0	1	-3	-2
S-041	0	0	5	0	0
S-053	-1	0	1	-1	-1
S-054	-1	0	1	-2	-2
S-067	0	0	0	0	0
S-069	1	2	3	-2	-2
S-071	-1	0	1	-1	-1
S-098	-2	0	2	-4	-4

The attenuation affect causes the impact on several of the parametric cases to be very small, a single LEED-EB point, including:

- Reducing the area air conditioned in schools by 15%
- Reducing the number of hospital beds by 15%
- Reducing the number of floors for hospitals by 15%

- Reducing the number of operating hours for schools and office buildings by 15%
- Reducing the number of occupants in office buildings by 15%
- Reducing the number of computers for schools and office buildings by 15%
- Reducing the number of students in schools by 15%.

For schools, several permutations included larger affects but again due to the step change nature of the points under LEED-EB, few conclusions can be drawn, see Table 50 below.

Table 50 – Several School LEED-EB Impacts

Building	*Cooking Present*	*Mechanical Ventilation*	*15% Area Heated Reduction*	*15% Months In Use Reduction*
S-003	-1	-2	-1	-1
S-037	-2	-3	-1	0
S-041	0	4	0	0
S-053	-1	-1	-1	0
S-054	-1	-2	-1	0
S-067	0	0	0	0
S-069	-2	3	-2	-2
S-071	-1	-1	0	0
S-098	-3	-4	-2	-1

6.6 Discussion

With only 10 out of 85 possible points in LEED-EB directly tied to actual energy use, it is very possible for a building to achieve a rating of certified or higher without showing better than average energy performance. This may be inconsistent with the common understanding of a green building that, for many, implies excellent energy performance.

The mapping of a four percentage point change in the ENERGY STAR for Buildings rating to a single point in LEED-EB means that at times large decreases in energy use are needed to increment a LEED-EB point and at other times when the building is already near the thresholds, only a small change in energy use can add a new LEED-EB point. This “stair step” approach may discourage energy savings measures that do not result in large changes to the overall building energy use even if cost effective on their own. It also means that the input sensitivity analysis performed as part of the work did not always have consistent results.

7 BREEAM

7.1 Overview

In the United Kingdom, the British Research Establishment (BRE) provides the Building Research Establishment Environmental Assessment Method (BREEAM) as a way to "provide authoritative guidance on ways of minimizing the adverse effects of building on the global and local environment while promoting a healthy and comfortable indoor environment" (Baldwin 1998). BREEAM has been adopted or serves as a model for other government and non-government organizations in many other places in the world. BREEAM uses a point method where points are awarded for various impacts of the building in the various categories. The evaluation of BREEAM contained in this report is focused on the 2004 version. More recent versions of BREEAM were available at the time of the publication of this report but were not available in time for evaluation. For office buildings, for example, the 2004 categories were:

- Management – overall policy and procedural issues
- Health and wellbeing – indoor and external issues
- Energy – operational energy and CO2 issues
- Transport – transport related CO2 and location issues
- Water – consumption and leakage related issues
- Materials – environmental implications of material selection
- Land use – greenfield and brownfield site issues
- Ecology – ecological value of the site issues
- Pollution – air and water pollution issues except for CO2.

Points in each category are combined using environmental weightings to score overall rating. Finally, if the score exceeds different thresholds, the building is described as:

- Pass
- Good
- Very Good
- Excellent

BREEAM is much broader in scope than simply assessing the energy use of the building. It attempts to quantify the overall sustainability of the building.

While some guidance is provided for a self-assessment by the building operator or owner, the intention is that a licensed assessor would survey the building, review documentation on the building, and provide the rating. BREEAM can apply to both existing buildings and new construction and the inclusion of an assessor in the design or retrofit process is encouraged to achieve a desired rating. After review of the submitted documentation by the assessor, BRE formally provides the building certification.

A core checklist is used for all buildings being assessed under BREEAM and is the only portion needed for an assessment of an existing vacant building. For new construction, the core checklist and a checklist of design and procurement issues is used. For occupied existing buildings, the core checklist and a checklist of management and operation issues is used.

Within the Energy category, points are assigned for a variety of elements as shown in Table 51.

Table 51 – BREEAM for Office 2004 Points Available

Element	Core Points	Design and Procurement Points	Management and Operation Points
Submetering of substantive end-uses	12	8	6
Submetering of tenants	12	8	6
Envelope Losses	12 – 60	8 – 40	6 – 30
Net CO2 emission	0	8 – 80	6 – 60
Energy policy for staff	0	0	6
Energy audit every 3 years	0	0	6
Energy information to staff & training	0	0	6
Energy/CO2 monitoring	0	0	6
Energy/CO2 targeting	0	0	6
Movement toward energy/CO2 target	0	0	6
Regular maintenance for HVAC	0	0	6
Records of light cleaning and replacement	0	0	6

In addition, other areas of BREEAM include elements that affect building energy use. Some of the more significant areas are:

- Where 80% of office area is daylit
- Fine zoning of lighting controls
- Use of renewable energy
- Use of high frequency ballasts
- Company policy regarding energy
- Availability of building operating manuals
- Operable windows for cross ventilation
- Maintenance policy for boilers

Of the energy affecting elements for offices, only the envelope losses, net CO2 emissions, and CO2 emission reductions are quantifiable. They are quoted below (BRE 2003a,b,c) in Tables 52, 53 and 54.

Table 52 – BREEAM for Offices Losses Minus Gains Credit

Losses minus gains in kWh/m2, will be predicted according to the fabric and form of the building. Credits are awarded based on the scale below:
Above 70.01 and below -70.01 kWh/m2/year (0 points)
Between +/- 45.01 and 70 kWh/m2/year (8 points)
Between +/- 25.01 and 45 kWh/m2/year (16 points)
Between +/- 15.01 and 25 kWh/m2/year (24 points)
Between +/- 5.01 and 15 kWh/m2/year (32 points)
Between 5 and -5 kWh/m2/year (40 points)

Table 53 – BREEM for Offices Net CO2 Emissions Credit

Total Net CO2 emissions will be predicted. Credits are awarded based on the scale below:
Below 145 kg/CO2/m2/year (8 points)
Below 120 kg/CO2/m2/year (16 points)
Below 95 kg/CO2/m2/year (24 points)
Below 75 kg/CO2/m2/year (32 points)
Below 60 kg/CO2/m2/year (40 points)
Below 50 kg/CO2/m2/year (48 points)
Below 45 kg/CO2/m2/year (56 points)
Below 35 kg/CO2/m2/year (64 points)
Below 20 kg/CO2/m2/year (72 points)
Below 0 kg/CO2/m2/year (80 points)

Table 54 – BREEAM for Offices CO2 Improvement Credit

CO2 emissions are predicted and credits are awarded based on the percentage improvement over static ECON 19 benchmarks (CT 2003). Credits are based on the following scale:
15% improvement on benchmark (6 points)
30% improvement on benchmark (12 points)
45% improvement on benchmark (18 points)
55% improvement on benchmark (24 points)
60% improvement on benchmark (30 points)
65% improvement on benchmark (36 points)
70% improvement on benchmark (42 points)
80% improvement on benchmark (48 points)
90% improvement on benchmark (54 points)
100% improvement on benchmark (60 points)

No guidance is provided in the checklist on how this is specifically calculated. The training that the licensed assessors go through explains how these calculations should be performed and provides access to tools such as spreadsheets to automate the calculations.

7.1.1 Types of buildings

BREEAM assessments can be performed for a variety of buildings:

- Offices
- New Industrial Units (includes warehouses and non-food retail)
- New Superstores and Supermarkets
- Residences (under EcoHomes)
- Schools
- Retail Developments
- Hospitals
- Other Buildings (under Bespoke).

For each type of building, a different set of specific criteria has been set (except for Bespoke). This reflects that each type of building has unique issues that must be considered to determine how the building ranks in terms of sustainability. The checklists for the different buildings do contain many overlapping elements but each was developed specifically for a certain type of building.

Under BREEAM, buildings are assessed with or without air conditioning using the same rating scale. BREEAM specifically encourages building designers to consider using natural ventilation or mixed-mode ventilation instead of mechanical air conditioning.

For the CO2 credit related to ECON 19, the ECON 19 document (CT 2003) uses treated floor area as the measure of building area in the benchmark. Treated floor area is the gross floor area based on the inside dimensions of the exterior walls minus areas not heated.

7.1.2 Location

BREEAM was developed in the UK for use in the UK but since it was one of the first widely used protocols, it has been used in other countries. The checklists (BRE 2003a,b,c) do not indicate any type of adjustment for climate at all. It is likely that a licensed assessor would make an adjustment based on climate.

7.1.3 Qualifications

Buildings rated using the BREEAM method must meet a minimum number of points to score the lowest level "pass". The number of points implies that some requirements have been passed. BREEAM has no specific "prerequisites" like LEED has or requirements like those in ENERGY STAR for Buildings.

Elements such as adequate lighting, outside air and thermal comfort are minimum qualifications for other rating systems but for BREEAM they are just another area for which points can be awarded. Part of the BREEAM process is to encourage adequate lighting, outside air and thermal comfort. The BREEAM Office 2004 checklist for example, has 10 to 21 points for "where maintained lighting levels are between 350-400 lux and the louver design is in compliance with the addendum to Lighting Guide 3, 2001" and 10 to 21 points for proper ventilation and 10 points for proper thermal comfort under Health and Wellbeing Core list.

For BREEAM the licensed assessor prepares the paperwork on behalf of the building owner and submits it to BRE for certification.

7.1.4 Audience

While the recognition that achieving a certain rating using BREEAM is important for the building owner, designer or operator, the application of BREEAM is completed by a licensed assessor. The assessor receives specific training and passes a test to become licensed. The information that the assessor needs is gathered from an extensive audit, review of building operating procedures, and many times design documents.

7.1.5 Ease of Use

Licensed assessors work with building designers and operators to complete the BREEAM checklist and go through the process. From that perspective, the "ease of use" for the building owner is good. The building owner directs the designers and operator to provide information to the assessor who takes care of the assessment and paperwork. Part of the process is to take the assessor on a walk through "audit" of the existing building. From the certified assessor perspective, the BREEAM process requires training and study. BRE suggests a price for the assessment itself of several thousands of dollars. This implies days or weeks worth of effort. The entire process can take months from when the assessment starts to when it is complete and the building is certified.

Many of the questions on the BREEAM for Office checklist reflect aspects of the building design or operation directly. The envelope losses minus gains related points would require design documents concerning the layers of material in the walls, floor and roof and the type of windows used. The CO2 emissions and the improvement over the ECON 19 benchmark require following a more detailed estimating procedure utilizing the annual energy bills of the building.

The results of using BREEAM are two scores: an Environmental Performance Index (EPI) based on the core requirement, and a rating of pass, good, very good or excellent based on the combined checklist score from core/design and procurement or core/management and operation. Since the energy related points are based on fixed threshold values, no representation is made as to how the energy consumption of the building is compared to other similar existing buildings.

The BREEAM approach creates a rating based on many factors in the building but no further disaggregation of results concerning which parts of the building are responsible for larger energy usage is needed as part of the process. On the other hand, points can be awarded for regular energy audits, which would uncover specific ways that the building can be improved. In addition, points can be awarded for submetering which almost always results in a better understanding of the component loads in a building.

7.1.6 Use Statistics

BRE estimates that 25% to 30% of new office construction in the UK since 1990 has received a BREEAM rating (Lowe 2000). This has also been expressed as "some 400 major office buildings have been assessed" a few years earlier (Baldwin 1998b). For existing office buildings in the UK, approximately 1% have employed BREEAM for existing offices (Baldwin 1998b).

7.1.7 History

BREEAM history started in 1990 with the release of BREEAM 1/90 for new office designs only. It is considered the first environmental assessment method by many and has spawned other similar systems in other countries. A version for superstores and supermarkets was developed in 1991 (Crisp 1991). The office version was revised in 1993 with BREEAM 1/93 for new offices and BREEAM 4/93 for existing offices. Also in 1993, a version for new industrial units including warehousing and non-food retail units (Lindsay 1993) was made available. Later updates for office buildings include 1998 (Baldwin 1998), 2002, and 2004 (BRE 2003a,b,c).

7.1.8 Rating Cost

The BRE web site has recommended fee scale for licensed assessors and states "The following figures are intended to provide guidance on appropriate fee levels for BREEAM for Offices assessments. Assessors are free to amend these as appropriate in individual cases and to offer related consultancy services to provide early guidance prior to the formal assessment." These costs are presented below in Table 55 and are based on values as of November 2004. The last column shows the minimum BRE fee for quality assurance and certification which is normally 15% of the assessment fee.

Table 55 - Recommended Fee Scale for Office BREEAM (UK £)

Evaluation	*Base Cost*	*Cost per 1000 m2*	*Maximum*	*Minimum BRE Fee*
Design and Procurement	2,655	130	10,000	720
Management and Procurement	2,885	130	10,000	720
Post Construction Review	1,600	130	10,000	320
Building Performance Assessment	1,600	130	10,000	565
Use of ESICHECK	75	-	-	-

Assuming 1.85 British pounds to one U.S. Dollar is used, the following is the same table converted to U.S. Dollars as shown in Table 56.

Table 56 - Recommended Fee Scale for Office BREEAM (US$)

Evaluation	*Base Cost*	*Cost per 1000 m2*	*Maximum*	*Minimum BRE Fee*
Design and Procurement	4912	240	18,500	1332
Management and Procurement	5337	240	18,500	1332
Post Construction Review	2960	240	18,500	592
Building Performance Assessment	2960	240	18,500	1045
Use of ESICHECK	139	-	-	-

The recommended fee scale for providing BREEAM for Retail is shown in Table 57.

Table 57 - Recommended Fee Scale for BREEAM for Retail (UK £)

Retail Type	*Base fee* New Design	Fit outs	O&M	*Additional* Per 1000m2	Per function
General Retail outlet	3,500	3,000	3,000	65	175
Show room	3,500	3,000	3,000	65	175
Service provider	3,500	3,000	3,000	65	175
Department store	3,500	3,000	3,000	65	175
Restaurant/catering	3,500	3,000	3,000	65	175
Warehouse	3,500	3,000	3,000	65	175
Shopping center*	3,500	3,000	3,000	65	175
Retail Park**	3,000	2,500	3,000	65	175

* A group of 10 or more shop units > 5000 square meters
** A development with several shop units either grouped or stand-alone

Additional functions each increase the fee and include:

- Car Parks – Covered and/or uncovered
- Internal warehouse & storage areas
- Delivery yard
- Waste disposal facilities
- Bakery
- Laundry
- Catering/food court
- Frozen food and/or refrigerated food storage
- Staffrooms & staff office facilities
- Landscaped areas – internal & external
- Customer services – lifts, escalators & WC's/showers

The same table converted into US dollars is shown below on Table 58.

Table 58 - Recommended Fee Scale for BREEAM for Retail (US$)

Retail Type	*Base fee* New Design	Fit outs	O&M	*Additional* Per 1000m2	Per function
General Retail outlet	6,475	5,550	5,550	120	324
Show room	6,475	5,550	5,550	120	324
Service provider	6,475	5,550	5,550	120	324
Department store	6,475	5,550	5,550	120	324
Restaurant/catering	6,475	5,550	5,550	120	324
Warehouse	6,475	5,550	5,550	120	324
Shopping center*	6,475	5,550	5,550	120	324
Retail Park**	5,550	4,625	5,550	120	324

Note: See previous table for explanation of asterisks.

For industrial units the pricing is as shown in the following table, Table 59, in both British pounds and US dollars.

Table 59 - Recommended Fee Scale for BREEAM for Industrial

Area	*UK £*	*US$*
Up to 999 m2	3,000	5,550
Between 1000 m2 and 4999 m2	4,000	7,400
Over 5000 m2	5,000	9,250
Additional units	500	925

No guidance is provided for homes, schools or any of the remaining building types.

7.2 Technical Basis

7.2.1 Empirical Data

The BREEAM Offices 2004 management and operation checklist (BRE 2003c) uses a "percentage improvement over static ECON 19 benchmarks" to award points for CO2 emission reductions. ECON 19 is the commonly used name for Energy Consumption Guide 19 (CT 2003) published by the Carbon Trust, an independent company funded by the UK government whose "role is to help the UK move to a low carbon economy by helping business and the public sector reduce carbon emissions now and capture the commercial opportunities of low carbon technologies". ECON 19 defines four types of office buildings:

- Naturally ventilated cellular
- Naturally ventilated open-plan
- Air-conditioned standard
- Air-conditioned prestige

ECON 19 established best practice and typical energy use indices (EUI). Indices are given for the whole building and for major end-uses. The EUI's use treated floor area as the denominator. Treated floor area is defined as "gross areas less plant rooms and other areas (e.g. stores, covered car parking and roof spaces) not directly heated" and further defines gross internal area as "total building area measured inside external walls".

ECON 19 does not vary by climate. This may be due to the relatively small variation in climate in the UK but it may also assume an adjustment in climate based on degree-days is made. ECON 19 does reference another related publication concerning degree-day adjustment methodology. It is not known whether adjusting for degree-days is required for BREEAM.

While ECON 19 does set the benchmark, the source of data behind the values is not clearly stated. In the background section of that document it states "The energy use benchmarks presented in this Guide are based on data gathered in the 1990s and reflect both of these trends." Upon further investigation, it was concluded that the benchmark values were based "on the experience built up from several hundred surveys of office buildings, most of which were carried out in the 1990s. A typical benchmark is the average for the survey sample while a good practice benchmark is roughly the performance achieved by the top quartile" (Lillicrap 2004). Further, many of these surveys were based on the "PROBE" studies by Bill Bordass, which may be found at http://www.usablebuildings.co.uk/. It is not clear if the exact method of deriving the ECON 19 benchmark values were actually based on a statistical analysis of a data set or if they simply were professional judgments of someone with a great deal of experience in building energy use. While some of the PROBE studies are available publicly, not enough information is provided to reconstruct the ECON 19 estimates that are the basis of the BREEAM benchmark. The use of ECON 19 benchmark values is not limited to the BREEAM rating system but is used for several other benchmarking systems. This, while not the same as statistical rigor, does imply that the values do make sense to a number of professionals in the UK.

7.2.2 Use of ASHRAE standards

BREEAM makes no use of ASHRAE standards and instead uses standards and guidelines developed in the UK.

7.2.3 Documentation available

To understand the BREEAM rating system, the first place to go is the web site:

http://products.bre.co.uk/breeam/

For additional information see

- BREEAM 98 for Offices (Baldwin 1998)
- BREEAM/New Industrial Units Version 5/93 (Lindsay 1993)
- BREEAM 2/91 An Environmental Assessment for new Superstores and Supermarkets (Crisp 1991)

These documents give more details concerning the way such assessments should be performed and contain overviews of many of the issues being addressed by BREEAM but are not a technical derivation of the methods used in BREEAM.

The actual checklists for the 2004 version for offices are available on line:

- BREEAM Offices 2004 Core Credits Only - Assessment Prediction Checklist (BRE 2003a)
- BREEAM Offices 2004 Design and Procurement - Assessment Prediction Checklist (BRE 2003b)
- BREEAM Offices 2004 Management and Operation - Assessment Prediction Checklist (BRE 2003c)

Literature that does provide details as to the steps taken to justify individual credits from the checklists are available to people training to be, or already are, licensed assessors. Those documents were not available for review as part of this study.

7.2.4 Calculation details

While BREEAM has many elements that relate to energy consumption, the areas that require calculations to be performed for BREEAM Office 2004 (BRE 2003a,b,c) are:

- Envelope losses
- Net CO2 emissions
- CO2 emission reductions

These are each quantifiable and serve as the “benchmark” portion of the energy related elements.

The core checklist for offices says "losses minus gains” in kWh/m2 will be predicted according to the fabric and form of the building." A formal assessment would use a spreadsheet created by BRE called Fabric and Form Calculator. The Fabric and Form Calculator analyses both the heat losses and the heat gains associated with the building being evaluated. The primary inputs are:

- Wall u-values
- Wall dimensions and orientations
- Window u-values
- Window dimensions and orientations
- Ventilation rates
- Any internal gains.

Using this information along with some assumptions and other data required, an estimation of the losses minus gains is calculated.

The design checklist for offices says "Total Net CO2 emissions will be predicted" but doesn't say how or what tool should be used. According to BRE, when a formal assessment is carried out a calculation will be needed to predict the total net C02 emissions by using an energy modeling program. The energy modeling program would need to be in compliance with the Building Energy and Environmental Modeling (CIBSE 1998) checklist. The modeling checklist is contained in Appendix B and is not a set of criteria but rather a list of possible features to be used when selecting an energy analysis software program.

The management checklist for offices says "CO2 emissions are predicted and credits are awarded based on the percentage improvement over static ECON 19 (CT 2003) benchmarks." Nevertheless, ECON 19 does not provide many of the details that would normally be needed to perform a calculation. According to BRE, a calculation is carried out when doing a formal assessment using various pieces of data to estimate the percentage of improvement over ECON 19. A spreadsheet has been created by BRE to aid in this process and is available to certified assessors only. ECON 19 does include factors for calculating carbon dioxide emissions although other factors may be used by assessors. The ECON 19 factors are shown in Table 60.

Table 60 – Carbon Dioxide Emission Factors from ECON 19

Fuel	*kgCO2/kWh*
Electricity (Average)	0.52
Natural Gas	0.19
Oil	0.27
Coal	0.32

7.2.5 Validation

Several technical papers comparing the overall BREEAM methodology with other environmental assessment methods exist but none of those found focused on the energy benchmarking aspect of BREEAM.

7.2.6 Weight of Energy

The points assigned to different areas based on the BREEAM Offices 2004 Assessment Prediction Checklists for Core Credits Only (BRE 2003a), Design and Procurement (BRE 2003b), and Management and Operation (BRE 2003c) are shown in Table 61.

Table 61 – BREEAM Offices 2004 Point Distribution

Checklist	Core	Design and Procurement		Management and Operation	
SubType	n/a	Core	Other	Core	Other
Management	0	0	160	0	148
Health/Wellbeing	143	130	20	91	63
Energy	84	56	80	42	108
Transport	156	104	0	78	12
Water	48	48	0	36	12
Materials	100	16	82	50	50
Land Use	0	0	30	0	0
Ecology	0	0	126	0	0
Pollution	176	132	12	154	14
TOTAL	707	486	510	451	407
%Energy	12%	12%	16%	9%	27%

Overall, 14% of the points are related to energy for Design and Procurement and 17% for Management and Operation when including core points.

The weighting between the different categories was determined by, or at least influenced by, a survey trying to achieve industry consensus (Dickie 2000). Sixty people representing seven different interest groups were surveyed:

- Government policy makers and researchers
- Construction professionals
- Construction materials produces and manufacturers
- Property and institutional investors
- Environmental activists and lobbyists
- Local authority policy makers and planners

- Academics and researchers.

The number of core points in each of the three cases is used to assess the Environmental Performance Index Score (EPI). EPI is a scale from 1 to 10 where 1 is approximately 20% of the core points and another EPI is added for each 7% to 8% more core points up to 10 which is the highest EPI with approximately 75% of core points.

The overall BREEAM rating is based on the total of the core and other points and is not assessed for core only buildings. This is 996 points for Design and Procurement and 858 points for Management and Operation. The following score ranges are shown in Table 62 and 63 as the estimate for the probable BREEAM rating.

Table 62 – Score Ranges for BREEAM Ratings

Rating	Design and Procurement	Management and Operation
Pass	235 – 405	50 – 220
Good	385 – 550	200 – 370
Very Good	530 – 695	350 – 520
Excellent	675 +	500 +

Table 63 – Minimum Percentage for BREEAM Ratings

Rating	Design and Procurement	Management and Operation
Pass	24%	6%
Good	39%	23%
Very Good	53%	41%
Excellent	68%	58%

The difference in minimum percentages needed to achieve different ratings varies considerably between the two types of ratings.

Additionally, the assignment of points seems to be based on a subjective opinion of increasing difficulty based on a nearly linear relationship between increased improvement and points given. These assumptions seem faulty since the design challenges to go from 90% to 100% are probably significantly more difficult than going from 45% to 50% improvement.

7.3 Application

Similar to LEED-EB, BREEAM is an environmental rating method that includes energy but also includes other categories including management, health and wellbeing, transport, water, materials, land use and ecology, and pollution. BREEAM is not a single rating method, each building type has significantly different requirements. This allows the rating method to match construction practices and other materials developed for that building class such as energy benchmarking systems. Since questionnaires were used to gather information on the buildings in order to estimate which credits should be counted, only the primary buildings were assessed and not the secondary buildings.

The primary buildings included office, school, lodging and hospital. BREEAM does not have an assessment method for hotels. BREEAM references a non-BREEAM system for health buildings called NHS Environmental Assessment Tool, NEAT, where NHS is the National Health Service part of the United Kingdom government. NEAT was developed by BRE, the Building Research Establishment, which also developed and maintains BREEAM.

BREEAM further divides each building type method into categories:

- Design and Procurement for new building designs
- Post Construction Assessment for new building designs
- Fit Out Assessment for existing retail buildings
- Management and Operation for existing buildings.

Since the focus of the web-based rating methods are all on existing buildings, the Management and Operation category was the focus of this report. The BREEAM method for schools is only on Design and Procurement so they will not be assessed as part of this section. The building type that remains for the primary buildings is office building and so the focus of the analysis will be on office buildings.

BREEAM is evolving and started out in 1990 with office buildings, which was updated in 1993, 1998, 2002, 2004, 2005 and 2006. When the original evaluation was completed, it reported on the 2004 version of BREEAM for Offices but since then the 2005 and 2006 versions have been released. Similarly, the school version of BREEAM has been updated since the 2004 version in 2005 and 2006. The 2006 version has changed the overall scale for the points given. In the BREEAM Office 2004 version for Management and Operation in the Energy Category, 150 points were available with 50, 200, 350 and 500 being the thresholds for ratings pass, good, very good, and excellent, respectively. The total number of points available for BREEAM Office 2004 was 858 points. For the 2006 version, the Energy Category has 14.74 points available with 20, 35, 50 and 65 being the respective thresholds. This means that the fraction of points related to energy has been reduced in the 2006 version compared to the 2004 version. To get a very good score in 2004, the maximum energy points corresponded to 43% of the score but with the 2006 version it is down to 29% of the score. The fraction of points for energy is reduced for the other ratings levels also.

Table 64 describes the difference in the energy category for BREEAM over time.

Table 64 – Office Energy Management and Operation with BREEAM

	2004/2005	2006
End-use submetering	4.0	4.3
Tenancy submetering	4.0%	4.3
Fabric load	20.0%	n/a
CO2 Emissions	40.0%	43.6
Energy policy	4.0%	4.3
Regular audit	4.0%	4.3
Information and training	4.0%	4.3
Energy/CO2 monitoring	4.0%	4.3
Energy/CO2 targeting	4.0%	4.3
Achieving energy/CO2 targets	4.0%	4.3
HVAC maintenance	4.0%	13.0
Light maintenance	4.0%	4.0
External lighting controls	n/a	4.0

The 2004 and 2005 versions for office buildings were nearly identical, the only difference is the reference used for the energy policy changed from Good Practice Guide 186 to 376. The 2006 version was a significant change including:

- Eliminating the fabric load credit
- Adding a credit for efficient external lighting controlled by daylight
- The CO2 emissions calculation method changed
- The preventive maintenance expanded to include ventilation, humidification, boilers, burners and domestic hot water.

The CO2 emissions calculations changed from being based on the ECON 19 benchmark directly to use the 2002 Building Regulations that referenced ECON 19. Since the European Union Energy Performance for Buildings Directive, EPBD, (OJEC 2002) the Building Regulations included a method for determining carbon emissions for existing buildings that uses ECON 19. Since building owners need to comply with the regulations, it then requires no additional effort to attempt to gain this BREEAM credit. Since all the recent versions of BREEAM use ECON 19 either directly or indirectly, it will be used for determining the CO2 emission points.

To simplify the questionnaires and prompt more accurate answers, some of the BREEAM credits were reworded or changed. This report is only examining the Energy portion of the Management and Operation for BREEAM for Offices. The following table, Table 65, shows the BREEAM questions and the corresponding question from the questionnaire. Clearly, a voluntary response as part of a simple questionnaire is far from the rigor of obtaining a BREEAM rating and some degree of error must be assumed for the credits shown as “awarded” for the BREEAM method. Review of the full language used for each credit is helpful while reviewing the following table, Table 65.

Table 65 – BREEAM Survey Question Mapping

Credit	Mapping for Award
End-use submetering	Either from LEED EA Credit 5.1, 5.2, and 5.3 Performance Measurement: Enhanced metering Or, from questionnaire. Response of Yes to all of the following: Is lighting electric separately metered? Are plug or process electric separately metered? Is cooling electric separately metered? Is heating energy separately metered? Is fan electric separately metered?
Tenancy submetering	From questionnaire. Points given if Yes to: Are tenants separately metered? And two or greater for the question: How many companies are in the building?
Fabric load	Assumed no points any buildings for Fabric load credit because large number of difficult to gather information needed including insulation values for existing buildings. Also fabric and form calculator not made available for the research project.
CO2 Emissions	Used ECON 19 as basis supplemented with CIBSE TM 22 to calculate points.
Energy policy	From questionnaire. Points given if Yes to: Written and distributed an energy policy?
Regular audit	From questionnaire. If year was 2002 or later for question: Year of last energy audit.
Information and training	Either from LEED EA Credit 3.1 Building Operations and Maintenance: Staff Education Or, from questionnaire. Response of Yes to: 24 hours of maintenance staff training annually
Energy/CO2 monitoring	Either from LEED EA Credit 5.1, 5.2, and 5.3 Performance Measurement: Enhanced metering Or, from questionnaire a positive response to one of the of the following: Target reduction of energy use. Movement toward target reduction of energy use. Track, record and report emission reduction efforts?
Energy/CO2 targeting	Either from LEED EA Credit 5.1, 5.2, and 5.3 Performance Measurement: Enhanced metering Or, from questionnaire a positive response to one of the of the following: Target reduction of energy use. Movement toward target reduction of energy use. Track, record and report emission reduction efforts?
Achieving energy/CO2 targets	From questionnaire. Points given if Yes to: Movement toward target reduction of energy use
HVAC maintenance	Either from LEED EA Credit 3.2 Building Operations and Maintenance: Building Systems Maintenance Or, from questionnaire. Response of Yes to: Preventative maintenance program.
Light maintenance	From questionnaire. Points given if Yes to: Maintain records of lighting fixtures
External lighting controls	Assumed no points for any building. Not asked on survey since this is unique to BREEAM Office 2006 question that came out after survey.

The CO_2 emissions credit is normally computed based on a spreadsheet provided to raters by BRE called the "M&O energy calculator." Unfortunately, the M&O calculator was not made available from BRE for the research described in this report. Instead, a method that uses ECON 19 as a baseline called TM 22 (CIBSE 1999) will be used instead. This is the same as in BREEAM 2004 and 2005. In addition, TM22 is referenced as part of the Building Regulations, which is referenced by BREEAM for Offices 2006. The reference to TM22 in Building Regulations is not directly related to performing an analysis with ECON 19 but is related to benchmarking end-use components.

Buildings trying to comply with the Building Regulations are likely to use the National Calculation Method (http://www.ncm.bre.co.uk/) that includes software that implements the Simplified Building Energy Model. At the time of this report, that model was limited to new construction and rating operational energy use was not available.

The CO_2 emissions calculations were based on:

- Electrical energy consumption
- Gas consumption
- Steam consumption (converted into gas)
- Total floor area
- Questionnaire: Unheated floor area (used to compute treated floor area)
- Questionnaire: Prestige or headquarters building?
- Questionnaire: Naturally Ventilated?
- Questionnaire: Primary Cooling Source Percent Air Conditioned

The treated floor area was based on the total floor area used throughout the research from the buildings with an adjustment for the unheated portion. The questionnaire total floor area was often different from the area reported by the ENERGY STAR building profile. The ENERGY STAR area was considered more accurate since the questionnaire responses were frequently expressed as rounded figures. The fraction unheated based on the questionnaire responses was used to adjust the ENERGY STAR based areas. The treated floor area is defined in ECON 19 as the "gross floor less plan rooms and other spaces (e.g., stores, covered parking, and roof space) not directly heated."

ECON 19 contains benchmarks for four types of buildings:

1. Natural ventilated cellular
2. Natural ventilated open-plan
3. Air-conditioned, standard
4. Air-conditioned, prestige

Fourteen of the fifteen office buildings were 70% air conditioned or greater. The last office building contained a chiller. Given this, none of the buildings was considered either a Type 1 or Type 2 office building. The response for "Prestige or headquarters building" was used to categorize each building as Type 3 or Type 4.

TM22 contains three stages (methodologies) of calculating benchmarks based on ECON 19 with three increasing level of difficulty and accuracy:

- Stage 1 Initial assessment of energy performance
- Stage 2 Intermediate assessment allowing for unusual use
- Stage 3 Detailed assessment of buildings and each system

Stage 3 requires component-by-component energy estimates that were beyond the scope of the survey and would have been very difficult to collect data for. It is intended for use in conjunction with a detailed audit of a building. Stage 1 and 2 are similar focusing on total building utility consumption compared to ECON 19. Stage 2 includes a climate adjustment based on heating degree-days and for special spaces such as computer rooms and large kitchens. The special spaces adjustment in Stage 2 require either submetering of the special spaces or an audit level understanding of the equipment and the use of the equipment associated with the special spaces. Due to this, Stage 2 was used but only for the climate adjustment.

The TM22 document is accompanied with a spreadsheet that implements the three stages described. The spreadsheet was examined closely and the methodology is described below.

- The ECON 19 type of office (1 to 4) selects the benchmark energy consumption intensity for electric and gas based on values from ECON 19 Table B1.
- For the building being rated, the treated floor area is entered or estimated from gross floor area or the net floor area. For the analysis, treated floor area did not included unheated areas.
- For the building being rated, electricity, natural gas, oil and other fuel data is entered for one year in kWh.
- Special space energy uses are provided and the energy use for the special spaces per total treated floor area is subtracted from the energy intensity based on the total building (not performed for this analysis).
- The ratio of the ECON 19 heating degree-days (2462) and actual heating degree-days (base 15.5C) is the weather correction factor. For this analysis, heating degree-days base 60F from NOAA (NOAA 2002) was used since it is almost exactly 15.5C, the degree-day base used by ECON 19. A conversion of 1.8 was used to convert between Celsius and Fahrenheit based heating degree-days.
- A fraction of each utility that is weather dependant is calculated based on 80% for gas consumption. Since no default value for electric consumption was present, an estimate for electric heating energy consumption was based on 10%, close to the average of the electrically heated buildings in ENERGYguide.
- The weather adjustment factor minus one was multiplied by the portion of energy dependent on the weather and added to the entered energy intensity resulting in the annual consumption intensity for electricity and gas based on standard weather.
- The annual consumption intensity for electricity and gas based on standard weather are combined by a kgCO2/kWh factor for each energy source and this is also done for the energy consumption for electricity and gas for the selected benchmark from ECON 19.
- The difference between the kgCO2/m2 for the benchmark and the value based on annual consumption with standard weather divided by the benchmark value results in the percent better than benchmark for the building.

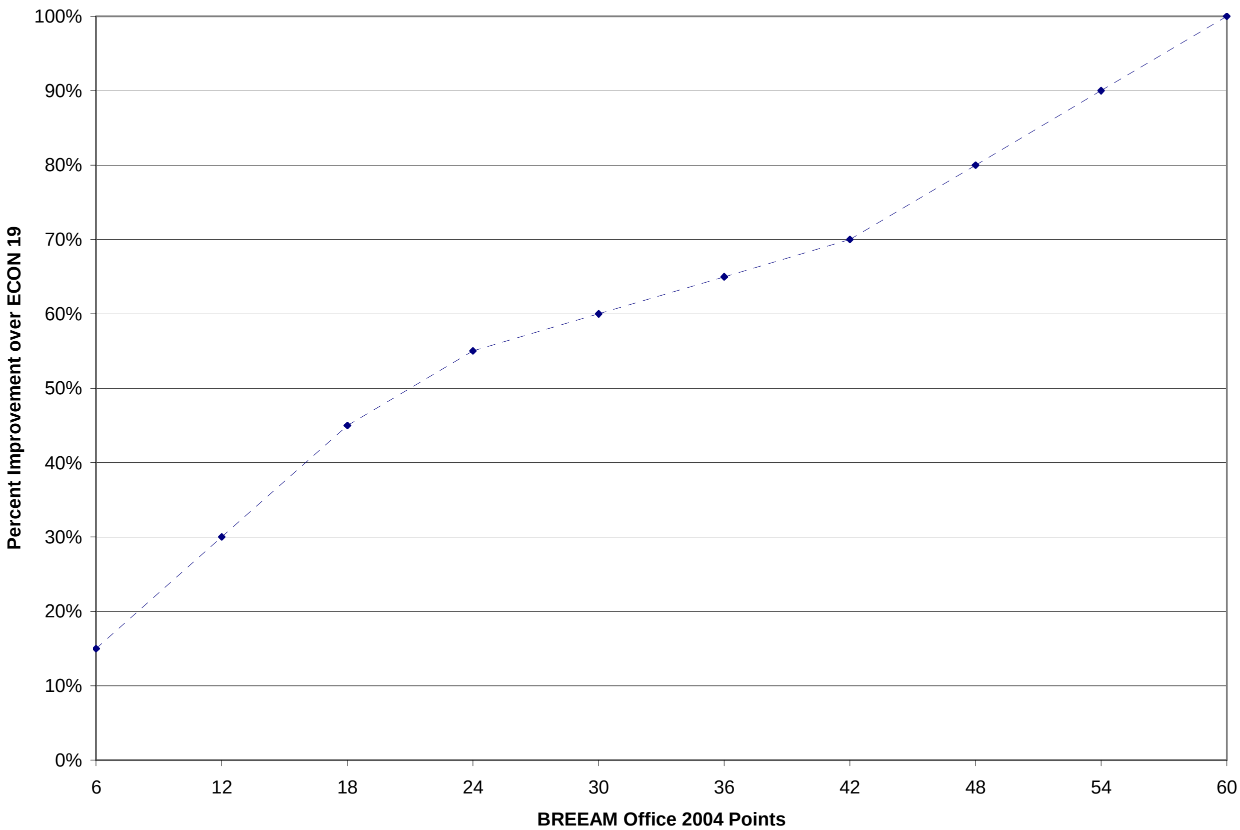
The percent improvement is turned into BREEAM points by using Table 66.

Table 66 – BREEAM Office 2004 CO2 Emission Improvement Points

Percent Improvement over ECON 19	*Points*
15%	6
30%	12
45%	18
55%	24
60%	30
65%	36
70%	42
80%	48
90%	54
100%	60

The number of points received for each change in percent improvement is not uniform starting at 15% for each 6 points, then 10%, 5% and 10% again for additional number of points, see Figure 47 below.

Figure 47 – Changing CO2 Emission Points with Improving Savings



The smaller improvement needed for additional points over 45% makes sense since the improvements become more difficult. The points gained when going beyond 70% improvement are even more difficult in reality but are rewarded more slowly. Perhaps this is recognition that saving more than 70% would be extremely difficult and applies to few buildings. For the analysis performed, the baseline buildings all received 24 points or less.

Overall, the BREEAM Office 2004 CO2 improvement credit is a good example of a single value benchmarking system with small adjustments for climate.

7.4 Baseline

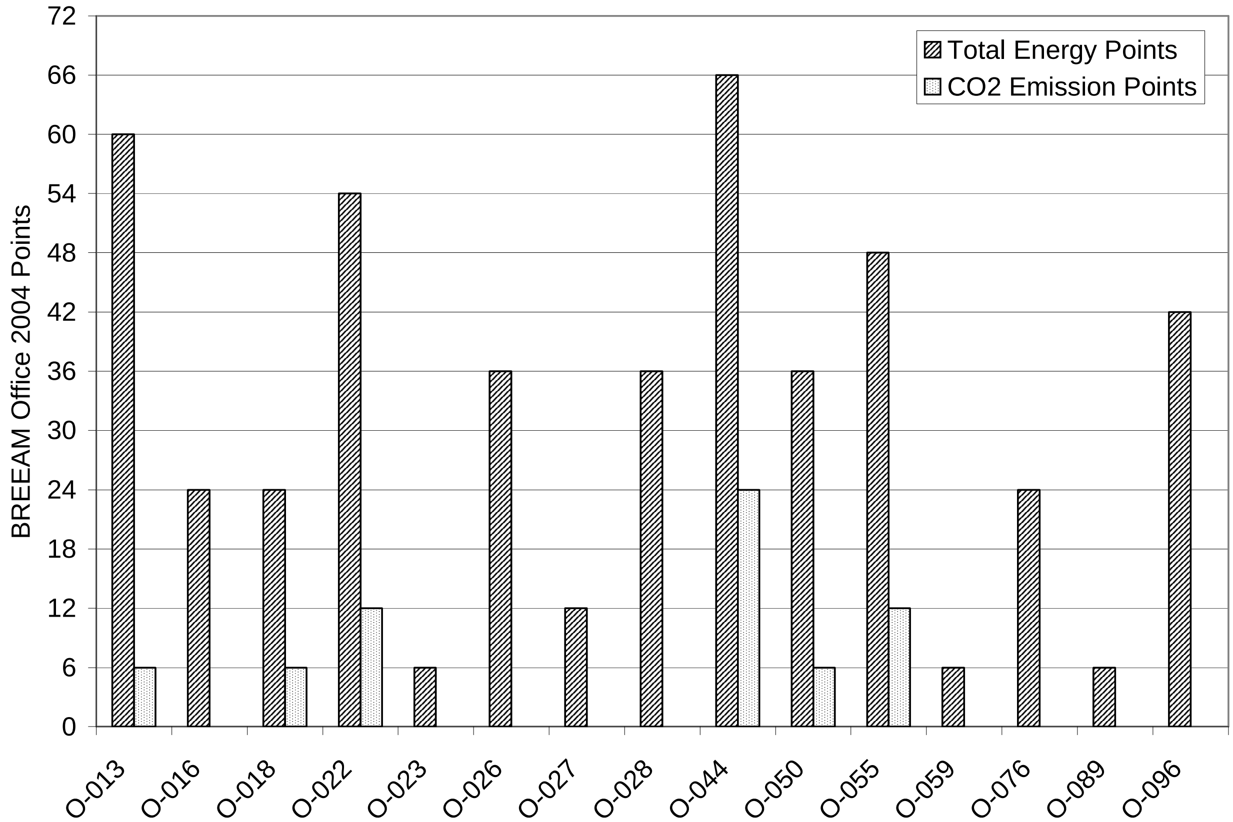
The primary data set includes fifteen office buildings which all responded to the questionnaire. The energy category points from BREEAM Office 2004 and the CO_2 improvement points are shown in Table 67.

Table 67 – Energy Points in BREEAM Office 2004

Building	*Total*	*CO2 Emission Points*
O-013	60	6
O-016	24	0
O-018	24	6
O-022	54	12
O-023	6	0
O-026	36	0
O-027	12	0
O-028	36	0
O-044	66	24
O-050	36	6
O-055	48	12
O-059	6	0
O-076	24	0
O-089	6	0
O-096	42	0

Figure 48 presents the data in Table 68. There is a weak correlation between buildings that receive high total energy points versus those that receive a high number of CO2 emission improvement points. The two buildings with the highest total energy points have 24 and 6 points from the CO2 emission improvement credit. Of the seven buildings with the smallest total energy points, only one had any CO2 emission points.

Figure 48 – Baseline Energy Points in BREEAM Office 2004



7.5 Input Sensitivity

By experimenting with the inputs for analysis of the CO2 emissions improvement credit, a better understanding of its function can be gained. This section examines a number of permutations to reveal this impact. One specific issue is that because the numbers of points possible are discrete values, that some of the changes appear unpredictable since they may just cross the threshold to receive the next six points or they may not. Table 68 shows the permutations that were analyzed, representing 165 different cases in total.

Table 68 – BREEAM Office 2004 Permutations

Permutation ID	*Description*
<none>	Baseline
COLDZIP	ZIP code for Portland Maine - New England - Census Div 1 - 04101
HOTZIP	ZIP code for Dallas Texas - West South Central – Census Div 7 – 75201
M15AREA	Area * 0.85
M15ENERGY	Electricity * 0.85, Natural Gas * 0.85, Other * 0.85
P15ENERGY	Electricity * 1.15, Natural Gas * 1.15, Other * 1.15
NOHTADJ	No adjusting energy use for standard climate
GOODPRAC	Use the ECON 19 good practice instead of typical.
L2CO2	Use the kgCO2/kWh conversion factors consistent with L2
TYPE4	Assess all building assume air-conditioned, prestige from ECON 19
TYPE3	Assess all building assume air-conditioned, standard from ECON 19

Table 69 shows the results of changing the inputs to BREEAM Office 2004 that also appear in the other rating methods. These common input change impacts reflect the step change aspect of the BREEAM Energy CO2 points that can be multiples of six. More than anything else, the change or lack of change for a particular building reflects more about how close the baseline building was to a step threshold. The table shows that most values are not changing with about one-third of the values changing by plus or minus six and one value changing by twelve.

Table 69 – Impact of Common Input Changes on BREEAM Office 2004

Building	Cold Location	Hot Location	%15 Energy Reduction	%15 Energy Increase	15% Area Reduction
O-013	0	0	6	0	-6
O-016	0	0	0	0	0
O-018	0	-6	0	-6	-6
O-022	0	-6	0	-6	-6
O-023	6	0	0	0	0
O-026	6	0	6	0	0
O-027	0	0	0	0	0
O-028	0	0	0	0	0
O-044	0	0	6	-6	-6
O-050	0	0	0	-6	-6
O-055	0	-12	6	-6	-6
O-059	6	0	0	0	0
O-076	0	0	0	0	0
O-089	6	0	0	0	0
O-096	6	0	0	0	0

Table 70 shows the remaining input parameters and how they impact the rating in BREEAM Office 2004. These input parameters were unique to BREEAM and did not exist in the other rating protocols. These impacts are only on the CO2 emissions credit in the Energy section of BREEAM Office 2004.

Table 70– Impact of Unique Input Changes on BREEAM Office 2004

Building	*L2 CO2 Factors*	*No Climate Adjustment*	*Good Practice Baseline*	*Prestige Basline*	*Non-Prestige Baseline*
O-013	0	0	-6	0	-6
O-016	0	0	0	6	0
O-018	-6	-6	-6	12	0
O-022	-6	0	-12	0	-12
O-023	0	6	0	0	0
O-026	0	0	0	0	0
O-027	0	0	0	12	0
O-028	0	0	0	0	0
O-044	-6	0	-12	0	-18
O-050	-6	0	-6	0	-6
O-055	0	0	-12	24	0
O-059	0	6	0	0	0
O-076	0	0	0	12	0
O-089	0	6	0	0	0
O-096	0	6	0	0	0

Again, the stair-step nature of the awarding of points in multiples of six makes drawing conclusions difficult. The fact that any changes occurred when the CO2 emission factors were changed is unfortunate since many different sets of CO2 emission factors are commonly used and well justified. Table 71 shows the actual values for the CO2 emission factors used. The Building Regulations factors are based on Carbon emissions and have been converted into CO2 emission factors. The 2% difference for gas probably had less impact than the almost 10% difference for electricity.

Table 71 – CO2 Emission Factors from ECON 19 and Buildings Regulations

Source	*Electric (kgCO2/kWh)*	*Gas (kgCO2/kWh)*
ECON 19	0.46	0.19
Building Regulations	0.414	0.194

Another conclusion that can be drawn from the table of impacts for the unique input changes is that the choice of baseline is critical. The impacts of changing baseline conditions range from –18 to 24, which was a significantly bigger impact than the –6 to 6 for the 15% energy and area changes. The choice of baseline is somewhat subjective. The BREEAM Office 2004 checklist states "CO2 emissions are predicted and credits are awarded based on the percentage improvement over static ECON 19 benchmarks." This sentence does not state which of the four types of ECON 19 buildings should be used so it is likely that it is left to the decision of the rater and the building owner. Since ECON 19 provides significantly higher baseline values for air-conditioned prestige (Type 4) buildings that would be the best baseline to choose if it was available. The definition of air-conditioned prestige buildings is "A national or regional head office or technical or administrative center." Most offices could be classified as an "administrative center" since that is the primary purpose for offices. The different values for the electricity and gas consumption for different baselines under ECON 19 are shown below in Table 72.

Table 72 – Different Baseline Consumptions in ECON 19

Type	*Building*	*Level*	*Electricity (kWh/m2-yr)*	*Gas (kWh/m2-yr)*	*Combined (kCO2/m2-yr)*
1	Natural Ventilated Cellular	Typical	54	151	54
		Good Practice	33	79	30
2	Natural Ventilated Open-Plan	Typical	85	151	68
		Good Practice	54	79	40
3	Air-Conditioned Standard	Typical	226	178	138
		Good Practice	128	97	77
4	Air Conditioned Prestige	Typical	358	210	205
		Good Practice	234	114	129

The Good Practice benchmarks are 37% to 44% smaller than the typical values. For typical air-conditioned buildings, the prestige value is 50% greater than the standard value. Specifically identifying the baseline to be used in any benchmarking system is critical to understanding any rating scheme.

7.6 Discussion

With 150 points associated with Energy of the total 858 points in BREEAM Office 2004, it is very possible to be rated as "pass" or higher and still have a building that is not energy efficiency or even average in energy use. This is further exasperated because only 60 of the 150 energy points are directly tied to the energy consumption of the building. This is a serious flaw in BREEAM because a building can be rated as pass, good, very good or even excellent and still has poor energy performance. This does not align with a common understanding of what a green building is.

Another serious issue with BREEAM is the lack of details concerning the method of calculations for achieving the CO2 emissions points under the Energy category. By limiting information to only certified raters, experts in the field cannot determine if the approach is valid. For this study, the lack of information meant that the calculation procedure used was based on an assumed approach that may or may not be accurate. In fact, given the multiple baselines present in ECON 19, it is not even clear which to choose. Greater disclosure of how points are calculated could only help those interested in determining for themselves if their building is likely to qualify for a BREEAM rating.

The mapping of a 5%, 10% or 15% change in the ECON 19 evaluation to the next level of points (6) in BREEAM means that at times large changes in energy use are needed to change the number of BREEAM points and at other times when the building is already near the thresholds, only a small change in energy use can add an additional six BREEAM points. This "stair step" approach may discourage energy savings measures that do not result in large changes to the overall building energy use even if cost effective on their own. It also means that the input sensitivity analysis performed as part of the work did not always have consistent results.

8 ENERGYguide

8.1 Overview

ENERGYguide from Nexus Energy Software is the only energy rating protocol described in this report which was developed and marketed by a business. No documentation existed for the technical details used in ENERGYguide until this project prompted the creation of a short white paper authored by the product manager at Nexus Energy Software (Marks 2004). The paper is brief and several sections of the paper are quoted in this section. According to the white paper:

> *Benchmark is an element of a suite of tools designed to help customers understand their energy use, manage it, and improve business operations. Clients (energy companies) use the tools as a vehicle to demonstrate value of their energy service to customer as well as to market/provide additional programs, products, and services. Originally released in 1999. Expanded for value-orientation and multiple facility (per user) features in 2003. Looking for a time-efficient, visually-rich, reasonably accurate presentation that encourages user to invest time in utilizing the Energy Prism Business Energy Management suite (ENERGYguide) and in improvement of his/her energy management operations.*

The same benchmarking system is available publicly on the www.energyguide.com web site. The protocol is based on statistics using the EIA CBECS data from 1992 and 1995. The benchmark is limited to total energy cost, gas energy cost and electric energy cost – no other benchmarking is shown. The score received is one of the following:

- Lower 25th percentile
- Average
- Upper 25th percentile
- Top 10th percentile
- Top 5th percentile

The annual energy cost is compared against normal distribution. The results screen also shows an energy appliance label type of display, see Figure 49.

Figure 49 – Label from ENERGYguide

The following text explains the general process to the user:

> *We've positioned your current energy use on our benchmark scale, developed from a national survey of similar facilities. We've made adjustments for weather conditions, facility size, fuel utilization, and other basic characteristics that you told us about your business. Every business is different, but we've tried to level the playing field to help gauge how you "stack up" against the competition. Use these performance benchmarks to assess: how much energy improvement is reasonable, and (if your business uses multiple fuels) which energy sources likely harbor "room for improvement".*

The exact derivation of the minimum, maximum and distribution of values along the “bar” is not described in the documentation.

8.1.1 Types of buildings

A wide variety of types is available from a pull down list of choices:

- Auto
    - Auto Sales
    - Auto Sales and Service Center
    - Auto Repair / Service Center
- Bakery
- Barber Shop / Salon
- Funeral Home
- Gas Station
- Grocery
    - Convenience Store
    - Convenience Store and Gas
    - Grocery
    - Grocery with Deli
    - Grocery with Bakery
    - Grocery with Deli and Bakery
- Health Club
- Hotel
    - Hotel
    - Hotel with Restaurant
    - Motel
    - Motel with Restaurant
- Laundry / Drycleaning
    - Self-serve / Coin-op
    - Commercial Laundry
    - Dry Cleaner On-premise
    - Comm. Laundry and Dry Cleaning
- Medical
    - Medical Clinic
    - Doctor's Office
    - Dental Clinic
    - Dentist Office
- Nursing Home
- Office Building - Office Space
- Printing - Copy Center
- Religious Facility
- Restaurant
    - Restaurant with Dining Area
    - Quick Service Restaurant
    - Restaurant and Bar
- Retail
- School
- Small Warehouse

The floor area is defined as total interior floor area. Recommendations on the site are to exclude parking, sidewalks and other exterior areas of a building. The user can choose which energy source is used for each major end-use as shown in Table 73.

Table 73 – Fuels Allowed by End-use

End-use	*don't have/ don't pay*	*Electricity*	*Gas*	*Propane*	*Oil*
Heating (primary)	X	X	X	X	X
Heating (secondary)	X	X	X	X	X
Cooling (primary)	X	X	X		
Cooling (secondary)	X	X	X		
Water Heating	X	X	X	X	X
Refrigeration	X	X			
Cooking	X	X	X	X	
Laundry	X	X	X	X	
Interior Lighting	X	X			
Exterior Lighting	X	X			

Every end-use allows for the option of "don't have/don't pay" for facilities where that end-use is included in the rent or does not get used. This allows facilities with or without air conditioning, or another end-use, to be fairly compared to its set of buildings.

8.1.2 Location

The protocol uses the entry of ZIP code to determine the heating and cooling impacts. According to the paper:

> *ZipCode matched to NCDC normal weather station (approx. 8000 in U.S., 5000 in Canada). A 3-segment linear model adjusts Heating and Cooling as a function of annual HDD and CDD respectively.*

Additionally, actual weather is compensated for by "linear annual HDD/CDD model to adjusted heating & cooling EUI" (Marks 2004b). This use of ZIP code implies that the protocol was intended for use exclusively in the United States. Users outside the U.S. could determine a ZIP code that is closest to their climate and get an approximate match. The statistical basis of the protocol is CBECS databases which cover only U.S. buildings. It is not clear if Canadian buildings are covered or not. No adjustments are made for climate effects on a smaller basis than the NCDC weather stations associated with each ZIP code.

8.1.3 Qualifications

No certification or pass/fail criteria are part of the protocol. Instead, the user is shown how their building compares to the building stock of similar buildings and is allowed to make their own judgment if improvement is warranted. No minimum criteria have been found concerning the use of the protocol. The maximum facility size is 99,999 sqft. No one besides the user of the protocol is involved in the process so no certification is provided or verification can be sought. Due to this, no steps are made to ensure that the building has adequate lighting, outside air or thermal comfort. Overall, the lack of certification may serve to diminish the value of the benchmark since it is unlikely to be perceived as an objective test if described in the promotion of the building to the public. Instead, the protocol may be best suited for owners of multiple buildings trying to determine where energy efficiency investments make the most sense.

8.1.4 Audience

Due to the small number of inputs required by the protocol, a wide variety of people may use it even without technical background. The use of actual utility bills means that it will be used after occupancy (at least one year) and is likely to be used by the building owner or operator or the facility manager. Anyone with access to the utility bills is likely to have the remaining information needed such as the area of the building and the energy source used by the various end-uses.

8.1.5 Ease of Use

On the main www.energyguide.com web page, the user is asked for their ZIP code and under "Analyze your use" chooses "business" and presses the button to continue. After a page of introduction, the user is prompted for Facility Type (see the list in the previous section), the floorspace, and weekly operating hours. Other inputs such as email address and rent or own and "how did you hear about us" are optional. The weekly operating hours input has the options of:

- About 40 hours
- 40 – 69
- 70 – 99
- 100 – 129
- Over 130
- Open 24 hours/7 days

Each entry has a link to help that provides a short description of the field.

After that a page is shown that recommends some options to save on utility bills and suggests that "a few more questions will better define the basics about your business and refine these results" with another button to continue. That page has the same entries already filled out and in addition asks for:

- Number of floors (1, 2, 3, 4 or more)
- Approximate age of facility (less than 10 years, 10 to 29 years, 30 to 50 years, more than 50 years, unsure)
- Fuels used by end-uses (see previous description)
- Percentage of area that is heated? (100%, 80-99%, 60-79%, 40-59%, 20-39%, below 20%, 0%)
- Percentage of area that is cooled? (100%, 80-99%, 60-79%, 40-59%, 20-39%, below 20%, 0%)
- Weekday, Saturday, Sunday opening time/start up
- Weekday, Saturday, Sunday closing time/shut down
- Seasonality of business

The user again sees some recommendations but now a "benchmark" option is also shown. If that is clicked a pie chart is shown of the fraction of energy cost that is from different end-uses. The user can click another link to see how the building compares to other businesses. The "energy label" type of graph is shown but shows an average value for all users. The user must click "View/update my utility bills" to enter their own consumptions. The annual energy consumption and average cost per kWh and therm may be entered. When that is entered, the "energy label" display is now showing the benchmark of the facility. These last few steps of entering the facilities actual energy use are not very intuitive and many people may not even realize that the "energy label" does not represent their use unless they take the step of clicking "View/update my utility bills."

Overall, the site claims that the benchmarking process takes two or three minutes. That is probably optimistic for someone coming to the site for the first time but it is certainly less than an hour including gathering up the utility bills and calculating a total annual use. Little guidance is provided for determining the average annual cost per kWh or therm that could prove confusing to a building operator.

Multiple facilities may be defined and if the user creates an account the information may be saved from session to session. To create an account the user provides first and last name, email address and password.

The outputs include several graphs including the “energy label” style of graph. In addition, pie and bar charts of the estimated energy cost for each end-use are shown for total cost, gas costs and electric costs. Overall, the outputs are easy to understand.

Anyone with access to utility bills for a building is likely to be able to answer the other questions related to the buildings operating hours and number of floors. Age of building, floor area and fuels used for each end-use may be more difficult to determine and may require questions being asked of the building operator or even the owner of the building if rented. For one building type, offices, various age of building entries seem to make no impact on the “energy label” graph. Fuels used by end-use and floor area make a more direct impact. For example, changing from gas to electric heating changed the range of the “energy label” from 1056 – 5984 to 1077 – 6101 for a ZIP code in the Chicago area.

Recommendations for how to improve the building are presented at several steps in the process and the cost for each end-use is estimated.

8.1.6 Use Statistics

About 30 utilities use the protocol, which have rated 100,000 facilities, almost all in the United States. In the past year, approximately 20,000 facilities have been evaluated. Most users rate one or two buildings using the protocol. The typical size of buildings evaluated is less than 40,000 square feet. This data was provided by private communication with Nexus Energy Software (Marks 2004b).

8.1.7 History

The ENERGYguide Benchmark module was originally released in 1999 and additional features were added in 2003 to allow multiple facilities per user. The development of the protocol was influenced by “utility’s own load research derived EUI values” (Marks 2004b). The factors used in deciding on the type of algorithm were (Marks 2004b):

- Ease of implementation
- East of use
- General acceptability
- Accountability of approach.

8.1.8 Rating Cost

The use of the www.energyguide.com web site appears to provide the same benchmark service as what was described as the “Energy Prism Benchmark Module”. The use of the www.energyguide.com web site is free and seems to be able to be used free for a number of buildings. The cost of the use for this service under the moniker of “Energy Prism Benchmark Module” is not known.

8.2 Technical Basis

8.2.1 Empirical Data

The source of data used in the benchmarking system on www.energyguide.com is described to be (Marks 2004):

> *For default, average, business segment specific, End-use EUIs (Btu/sq ft) from 1992 and 1995 EIA CBECs database. Model will swap in custom, client-specific EUIs from load research data in place of CBECs data, when available.*

For each type of building between 50 and 300 data records were used. The data was selected based on principal building activity and size. All buildings, not just recent construction, were used. Generally small to medium sized buildings were used under 100,000 square feet. Data was filtered by visual examination. A normal distribution for the data was assumed based on the mean EUI. It is anticipated that the protocol will be updated with the release of new version of CBECS (Marks 2004b).

The utilization of CBECS data is sound but since few details are provided on how this is performed, it is not clear if the methodology, filtering, or categorization of the data is robust. The CBECS data represents a large number of buildings and is well validated but care must be exercised in its use and since little other description is provided, it is not possible to draw any conclusions on what steps were taken. The focus on end-use EUI's is different than other benchmarking approaches described in this report. The use of the 1992 and 1995 CBECS databases instead of the most recent versions 1999 or 2003 does diminish the accuracy of the data as a reflection of typical building practice. Each of the CBECS surveys has over 6000 responses and great care is made to make sure the set is representational of the U.S. building population. The CBECS data is available for public download but it would be impossible to reproduce the way the data is used by the benchmark protocol without additional details that are not available.

8.2.2 Use of ASHRAE standards

No reference to any ASHRAE standards is provided in the white paper (Marks 2004) or on the www.energyguide.com web site.

8.2.3 Documentation available

No documentation is available concerning the ENERGYguide Benchmark Module or its implementation on the www.energyguide.com web site. The white paper that much of this review is based on (Marks 2004) has not been published and was created at the request of the ASHRAE research project. The textual description of the protocol in Marks (2004) is approximately one page and has paragraphs labeled:

- Overview
- Features of benchmark module
- Benchmark rankings
- Multi-channel
- Multi-lingual
- Underlying data source
- Basic methodology
- User's actual energy billing data

Several of these paragraphs have been quoted in their entirety in this report. No other technical papers have been found concerning this protocol.

8.2.4 Calculation details

The basic methodology used in the protocol is described below based on (Marks 2004):

> *Utilize the underlying data source, user's "basic facility profile", and user's fuel price to define the mid-point of the benchmark scale. Distribution/percentiles are approximated using a normal distribution approach.*
>
> *Adjustments: Square foot and EUI based by business segment. User selects from 18 primary business types. 24 secondary business types offered. Fuels assigned to end-uses by user's "basic facility profile." ZipCode matched to NCDC normal weather station (approx. 8000 in U.S., 5000 in Canada). A 3-segment linear model adjusts Heating and Cooling as a function of annual HDD and CDD respectively. Lighting and Cooking end-use EUIs are linearly prorated based upon customer's weekly operating hours. All other end-uses (see baseline screen shot for list) are "static" for the purpose of defining the mid-point of the yellow benchmark label.*

Additionally (Marks 2004b):

EUI values for each end-use. Consider end-uses paid for, % conditioned, linear annual HDD/CDD cooling model. Lighting EUI is linearly prorated relative to mean weekly hours open.

The total internal floor area is used as an input and should not include parking or sidewalks. Hours of operation directly affect the minimum and maximum values shown on the "energy label". The protocol is focused on energy cost so the cost per unit of electricity, gas and other fuels are combined based on average annual cost. Multiple linear regression is not used to compensate for any secondary factors and the only use of regression is for adjusting for actual weather data (Marks 2004b).

The number of occupants is not asked when using the protocol so it does not affect the results. Since the timing of the annual energy consumption number is not requested, it is unlikely that any adjustment for actual weather is made when using the protocol. The same could be said for buildings with higher than typical outside air requirements or unusually high electric usage (computer centers) since no input relates to that factor. Although no specific guidance is provided, the typical user would combine the costs from multiple meters serving the benchmarked facility. A facility with multiple uses could benchmark each use as separate facilities if they had separate meters for each use but that is not always the case. When a single meter handles a facility with multiple uses, it is not clear how that facility would be benchmarked.

Renewable energy sources that are on-site reduce the energy consumption at the meter and thus directly affect the rating of the building. Offsite renewable energy consumption is not handled any differently than any other utility provided energy source.

The calculation algorithm is not currently available.

8.2.5 Validation

Validation took the form of "each client utility who utilizes Nexus application. Approximately 30 utility's in U.S. 2 in Canada." (Marks 2004b). No public review of the protocol was conducted.

If the user of the protocol enters nonsensical values results may be shown as off the scale indicating to the user that incorrect information was entered. (Marks 2004b)

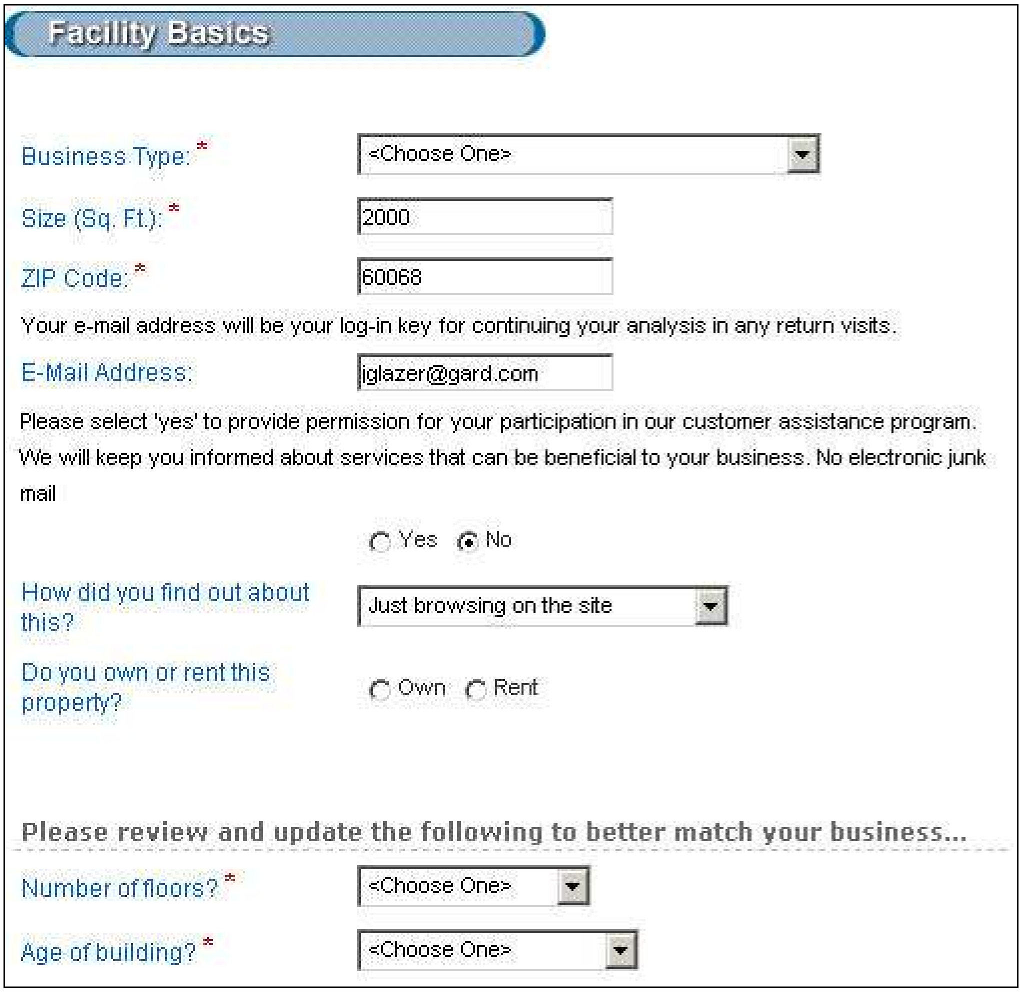
8.2.6 Weight of Energy

The protocol does not use points and is focused on energy cost so the entire benchmark is based solely on energy and the cost of energy.

8.3 Application

ENERGYguide inputs are shown in Figures 50, 51, and 52. Like Arch and Cal-Arch but unlike Energy Star, the same inputs are used for all building types. Of the web-based energy performance rating methods, ENERGYguide has the most required inputs. Many of the inputs are used by other rating methods under evaluation but some, such as describing the energy sources for each end-use, are unique to ENERGYguide.

Figure 50 – Input for ENERGYguide – Part 1


Facility Basics

Business Type: * <Choose One>

Size (Sq. Ft.): * 2000

ZIP Code: * 60068

Your e-mail address will be your log-in key for continuing your analysis in any return visits.

E-Mail Address: jglazer@gard.com

Please select 'yes' to provide permission for your participation in our customer assistance program. We will keep you informed about services that can be beneficial to your business. No electronic junk mail

Yes No

How did you find out about this? Just browsing on the site

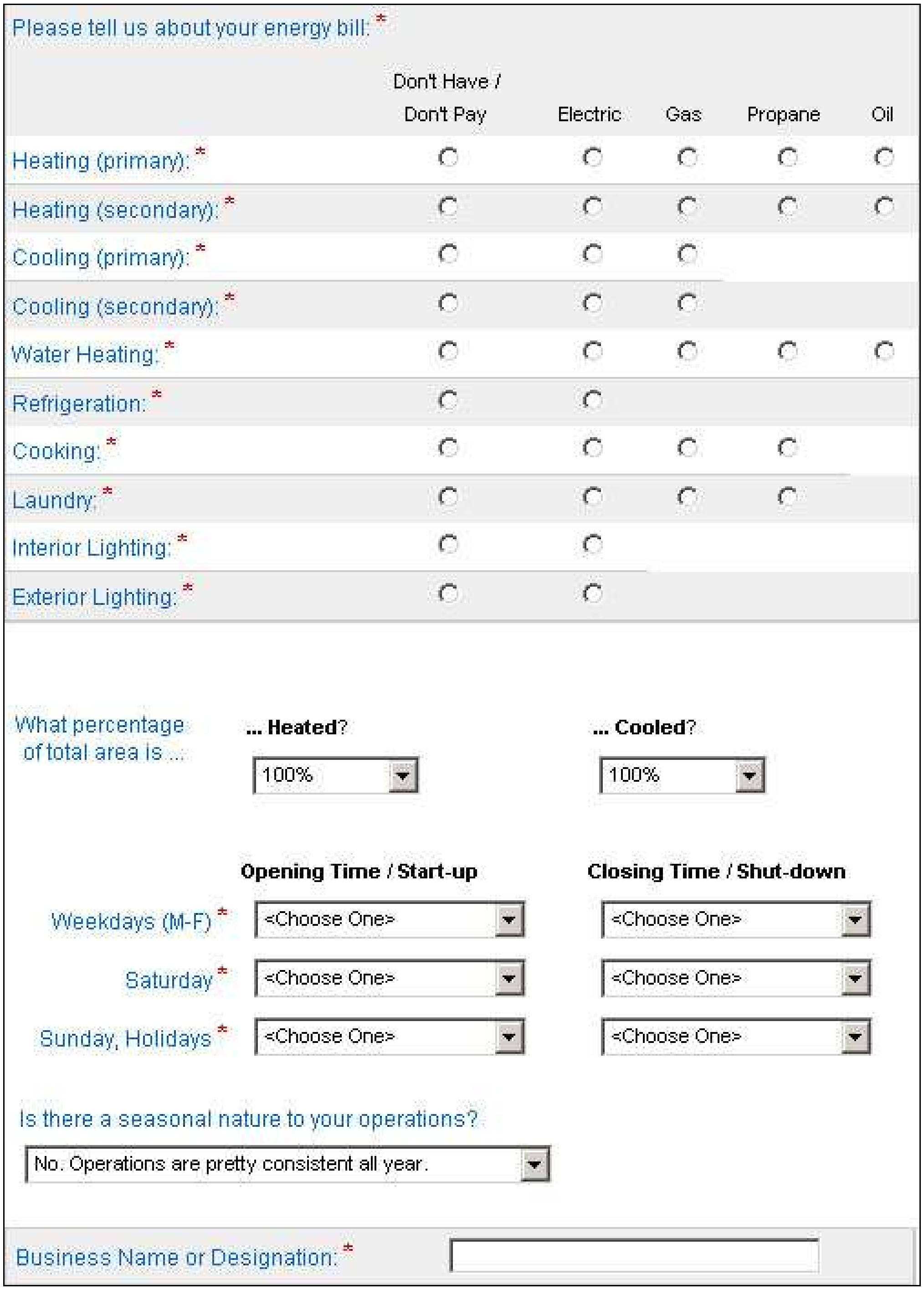
Do you own or rent this property? Own Rent

Please review and update the following to better match your business...

Number of floors? * <Choose One>

Age of building? * <Choose One>

Figure 51 – Input for ENERGYguide – Part 2



Please tell us about your energy bill: *

	Don't Have / Don't Pay	Electric	Gas	Propane	Oil
Heating (primary): *	○	○	○	○	○
Heating (secondary): *	○	○	○	○	○
Cooling (primary): *	○	○	○		
Cooling (secondary): *	○	○	○		
Water Heating: *	○	○	○	○	○
Refrigeration: *	○	○			
Cooking: *	○	○	○	○	
Laundry: *	○	○	○	○	
Interior Lighting: *	○	○			
Exterior Lighting: *	○	○			

What percentage of total area is ...

... Heated? 100%

... Cooled? 100%

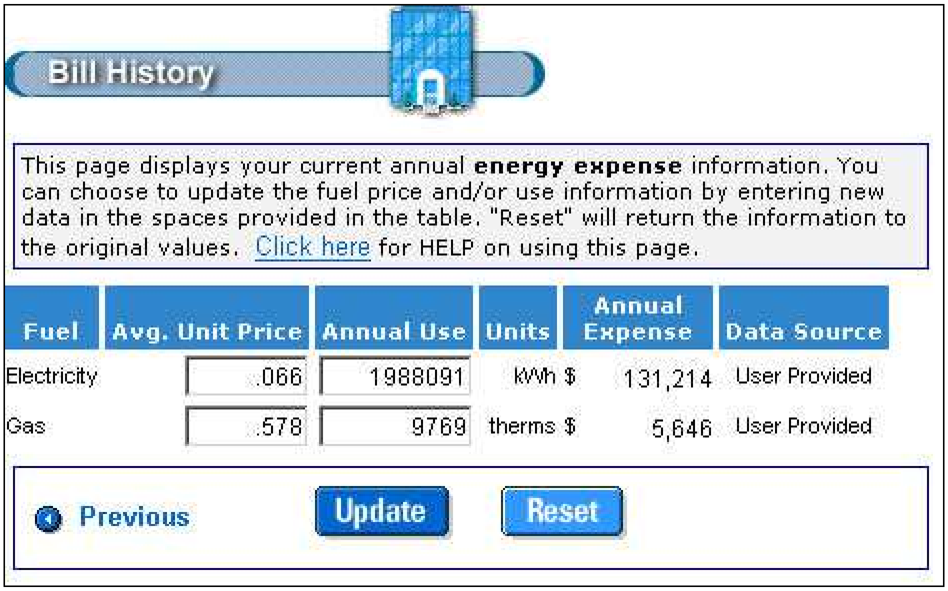
	Opening Time / Start-up	**Closing Time / Shut-down**
Weekdays (M-F) *	<Choose One>	<Choose One>
Saturday *	<Choose One>	<Choose One>
Sunday, Holidays *	<Choose One>	<Choose One>

Is there a seasonal nature to your operations?

No. Operations are pretty consistent all year.

Business Name or Designation: *

Figure 52 – Input for ENERGYguide – Part 3



ENERGYguide provides a graph of results showing the current estimated annual energy cost for the rated building and the minimum and maximum estimated annual energy cost for similar buildings. The pointer indicates where the rated building falls on the range of costs between the minimum and maximum annual energy cost of similar buildings. An example of the graphic used is shown in Figure 53. In addition to the graphic, the annual energy consumption, annual energy cost, and average cost for electricity and natural gas are displayed on the web page.

Figure 53 – Example Building Comparison Results for ENERGYguide

The first step was to determine if the pointer was located based on a distribution of buildings between the minimum and maximum values or if it was located based on a linear relationship between the minimum and maximum values. To do this, for each of the primary buildings the results graph like the one shown above was examined closely. It was copied from the web site and pasted into a spreadsheet where it was stretched to lengthen the distance between the minimum and maximum values. The location of the pointer and the minimum and maximum values were measured based on a 100 unit scale. The ratio of the pointer location based on graphical means was compared to the value computed using the following formula assuming a linear relationship between the minimum and maximum values:

$$\text{Rating} = (C_{maximum} - C_{current}) / (C_{maximum} - C_{minimum})$$

The graphical and computational method matched very well. The maximum absolute difference between the methods was 1.3% with the linear regression model having an R^2 of 0.999. Based on this outcome, the numbers presented in this section are all based on using the values from each rating given by the previous formula. This avoided the inaccuracies of a graphical method.

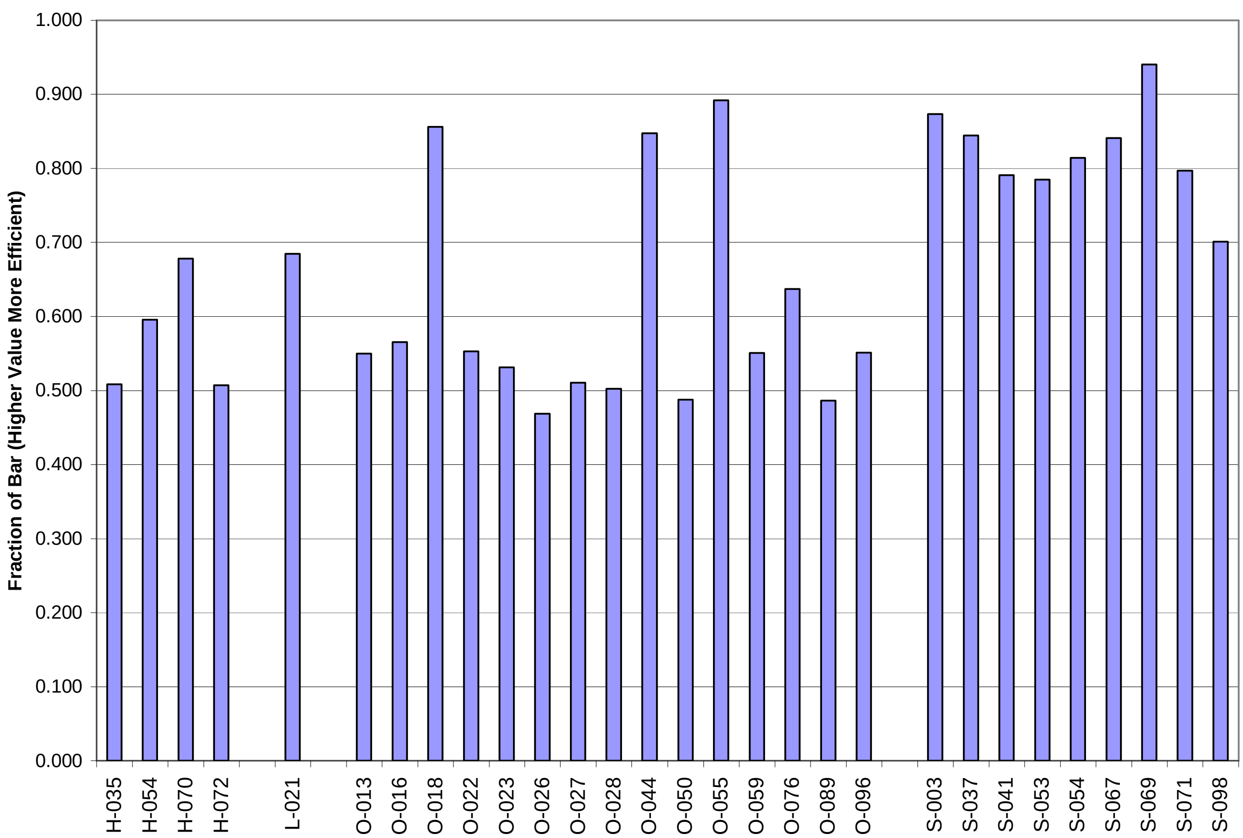
Please remember that the ENERGYguide does not provide the rating number that is described throughout the rest of this analysis. The web site provides the graphic with the minimum, maximum and current annual energy costs. For the analysis, these values were combined into a single rating value. The rating is shown on many of the following graphs as "Fraction of Bar", where the bar what is shown on Figure 44 and is the basis of the rating. The note "Higher Value More Efficient" on the graphs is to remind the reader of the process and the meaning of a higher value for the rating method.

One limitation that was not previously understood is that ENERGYguide will not accept buildings larger than 99,999 square feet. Unfortunately, only 9 of the 29 primary buildings collected as part of this project had floor areas of 99,999 square feet or lower. For the other 20 buildings, when rated with ENERGYguide, the floor area was set to 99,999 square feet and energy consumption was divided by the ratio of the actual building size divided by 99,999 square feet. The limitation of 99,999 square feet was not described on the web site or in the documentation provided by the vendor. This limitation also helps explain why no hospital building type is provided since they are usually well over this size limit. For the analysis, the Medical Clinic building type was chosen since it was the closest to hospital.

8.4 Baseline

The results of using ENERGYguide to rate the 29 primary buildings are shown in the following graph, Figure 54. The values show the position of the "current" building on the simple bar graph based on a percentage where the higher the number the closer to the minimum value. In this way, a taller bar in the graph represents a better rating for the building.

Figure 54 – ENERGYguide Baseline Ratings



The average rating and other simple measures for different categories of buildings are shown in Table 74. The largest range was for office buildings. On average schools rated the highest.

Table 74 – Baseline Ratings in ENERGYguide

	Minimum	Average	Maximum	Range
Hospital	0.507	0.572	0.678	0.171
Lodging	0.685	0.685	0.685	0.000
Office	0.469	0.599	0.892	0.423
School	0.701	0.821	0.940	0.239

8.5 Input Sensitivity

ENERGYguide has many inputs that the user provides as part of the benchmarking process. Due to the large number of inputs, not all buildings were rated for every permutation. All 29 buildings were rated for the permutations in ENERGYguide that were the same kind as the permutations in the other rating methods. Only four selected buildings were rated for the permutations that were unique to the inputs present in ENERGYguide. Four buildings were chosen, one from each building type of office, school, hospital and lodging. Some buildings were excluded and then a building that seemed most representative of the group of buildings was chosen. Table 75 summarizes the process for choosing the four buildings used in some permutations.

Table 75 – Picking Four Building for Some Permutations in ENERGYguide

Building	Reasons Not To Choose	Status
S-003	No gas usage	
S-037	Adjusted size	
S-041	Backup fuel use	
S-053		
S-054		
S-067	Backup fuel use	
S-069	Backup fuel use	
S-071		
S-098		Chosen
H-035	Backup fuel use	
H-054		
H-070		Chosen
H-072	Assumed gas use	
L-021		Chosen
O-013	Adjusted size	
O-016	Adjusted size	
O-018	Adjusted size	
O-022	Adjusted size	
O-023	No gas usage	
O-026	Adjusted size	
O-027	No gas usage	
O-028	Adjusted size	
O-044	Adjusted size	
O-050		Chosen
O-055		

Table 76 and Table 77 show each of the inputs, the number of buildings tested, and some of the permutation identifiers.

Table 76 – ENERGYguide Permutations

Input	#Buildings	Permutation
Business Type	4**	Hotel, Motel, Hotel with restaurant, Motel with restaurant, Medical clinic, Doctors office, Dental clinic, Dental office
Size (sq. ft.)	29	M15AREA (see Table X)
ZIP Code	29	COLDZIP HOTZIP (see Table X)
E-Mail Address	0	
Customer Assistance	0	
How did you find out about this	0	
Do you own or rent this property	4	Rent, Own
Number of floors	4	1, 2, 3, 4 or more
Age of building	4	Less than 10 years, 10 to 29 years, 30 to 50 years, More than 50 years
Heating (primary)	4	Don’t pay, electric gas
Heating (secondary)	4	Don’t pay, electric gas
Cooling (primary)	4	Don’t pay, electric gas
Cooling (secondary)	4	Don’t pay, electric gas
Water Heating	4	Don’t pay, electric gas
Refrigeration	4	Don’t pay, electric
Cooking	4	Don’t pay, electric gas
Laundry	4	Don’t pay, electric gas
Interior Lighting	4	Don’t pay, electric
Exterior Lighting	4	Don’t pay, electric
Percent of area Heated	4	100%, 80% to 99%, 60% to 79%, 40% to 59%, 20 to 39%, Below 20%, 0%
Percent of area Cooled	4	100%, 80% to 99%, 60% to 79%, 40% to 59%, 20 to 39%, Below 20%, 0%
Weekdays Opening Time/Start-up	29*	M15HRS (see Table X)
Weekdays Closing Time/Shut-down	29*	M15HRS (see Table X)
Saturday Opening Time/Start-up	29*	M15HRS (see Table X)
Saturday Closing Time/Shut-down	29*	M15HRS (see Table X)
Sunday/Holiday Opening Time/Start-up	29*	M15HRS (see Table X)
Sunday/Holiday Closing Time/Shut-down	29*	M15HRS (see Table X)
Seasonal Nature of Operations	4	Consistent all year, limited summer hours, limited winter hours
Business Name or Designation	0	
Electricity Avg. Unit Price ($/kWh)	4*	PRICEHIEG PRICELOWEG PRICEAVG
Gas Avg. Unit Price ($/therm)	4*	PRICEHIEG PRICELOWEG PRICEAVG
Electricity Annual Use (kWh)	29*	P15ENERGY M15ENERGY (see Table X)
Gas Annual Use (therms)	29*	P15ENERGY M15ENERGY (see Table X)

*Combined with adjacent items
** Depends on the building type

Table 77 –Permutation Details in 29 Building Cases for ENERGYguide

Permutation ID	*Description*
<none>	Baseline
COLDZIP	ZIP code for Portland Maine – New England - Census Div 1 - 04101
HOTZIP	ZIP code for Dallas Texas - West South Central - Census Div 7 – 75201
M15AREA	Area * 0.85
M15HRS	Starting and closing times revised to total the number of hours times 0.85
M15ENERGY	Electricity * 0.85, Natural Gas * 0.85, Other * 0.85
P15ENERGY	Electricity * 1.15, Natural Gas * 1.15, Other * 1.15

When not provided, the average electric and gas prices were left to default. The actual values used are shown in the following table, Table 78.

Table 78 – Pricing Used by Baseline ENERGYguide

Building	Electric	Gas
H-035	0.0690	0.5560
H-054	0.0560	0.9070
H-070	0.0540	0.8010
H-072	0.0600	0.8010
L-021	0.0730	0.6860
O-013	0.0659	0.5780
O-016	0.0700	0.0089
O-018	0.0600	0.0001
O-022	0.0690	0.5559
O-023	0.0800	-
O-026	0.0660	0.5780
O-027	0.0460	-
O-028	0.0630	1.0559
O-044	0.1010	0.7842
O-050	0.0900	0.6580
O-055	0.0700	0.9809
O-059	0.0800	-
O-076	0.0640	-
O-089	0.0800	-
O-096	0.0640	-
S-003	0.0750	-
S-037	0.0720	0.8800
S-041	0.0630	0.7570
S-053	0.0720	0.8800
S-054	0.0720	0.8801
S-067	0.1250	1.0200
S-069	0.1250	1.0200
S-071	0.0720	0.8800
S-098	0.0720	0.8800

For the permutations looking at different pricing options for energy, the following table, Table 79, shows the pricing used. The source of the electric and gas prices are based on DOE/EIA 2004 average commercial prices (EIA 2004a, EIA 2004b). The DOE/EIA price for natural gas was in dollars per 1000 cubit feet so it was converted into dollar per therm assuming 1013 Btu/cuft. The three different pricing scenarios were based on the actual average price and on a ratio of prices that was 30% higher and another ratio of 30% lower. The electric price was modified for the three scenarios and the gas price remained constant.

Table 79 –Pricing Permutation Details for ENERGYguide

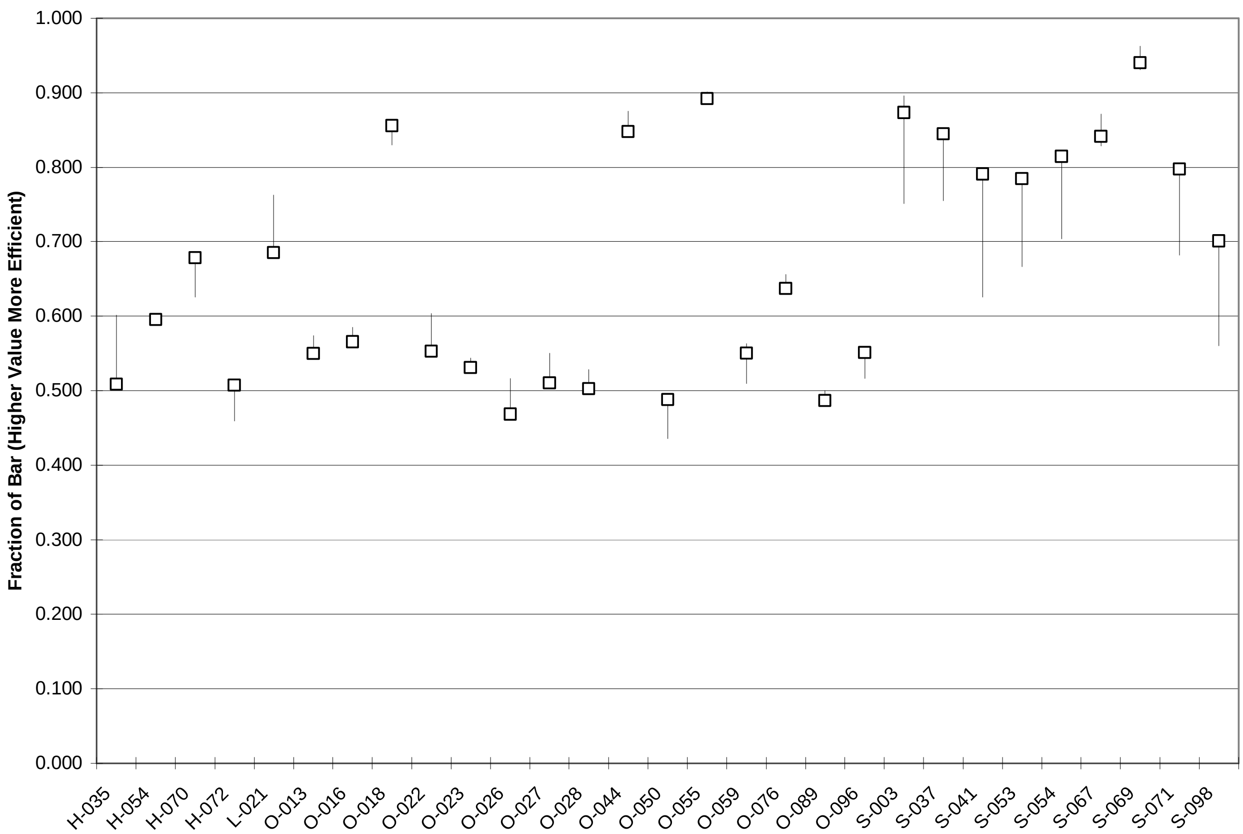
	Description	Electricity Price ($/kWh)	Gas Price ($/therm)
PRICEAVG	Average Prices	0.082	0.926
PRICEHIEG	High Electric to Gas Price Ratio	0.106	0.926
PRICELOWEG	Low Electric to Gas Price Ratio	0.057	0.926

Rating the primary buildings using the hot and cold climates resulted in a small impact on the rating, as seen in Figure 46. The two climate locations chosen were:

- Portland Maine 04101
- Dallas Texas 75201

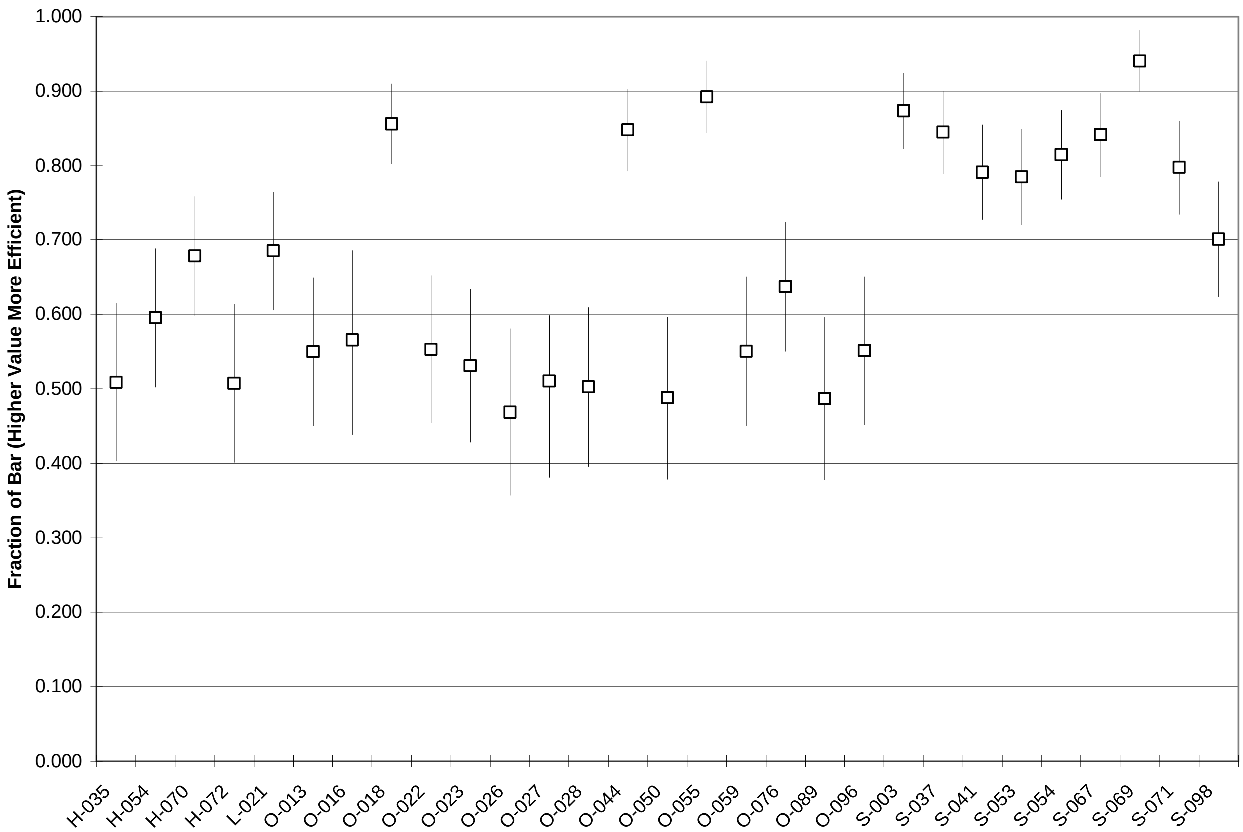
The schools showed the most sensitivity to the climate locations with office buildings showing the least sensitivity, as shown in Figure 55 below. On the graph the box represents the baseline rating while the top and bottom of the line represent the ratings at the two locations. The average range between the minimum and maximum ratings for office buildings was 3% while for schools it was 11% and hospitals it was 5%. For schools, the rating in Portland was consistently higher than for the same buildings rated in Dallas. Most hospitals have a higher rating in Dallas than their rating in Portland. Offices are mixed with some higher in Dallas and others higher in Portland.

Figure 55 – Ratings when Entering Hot and Cold ZIP Codes in ENERGYguide



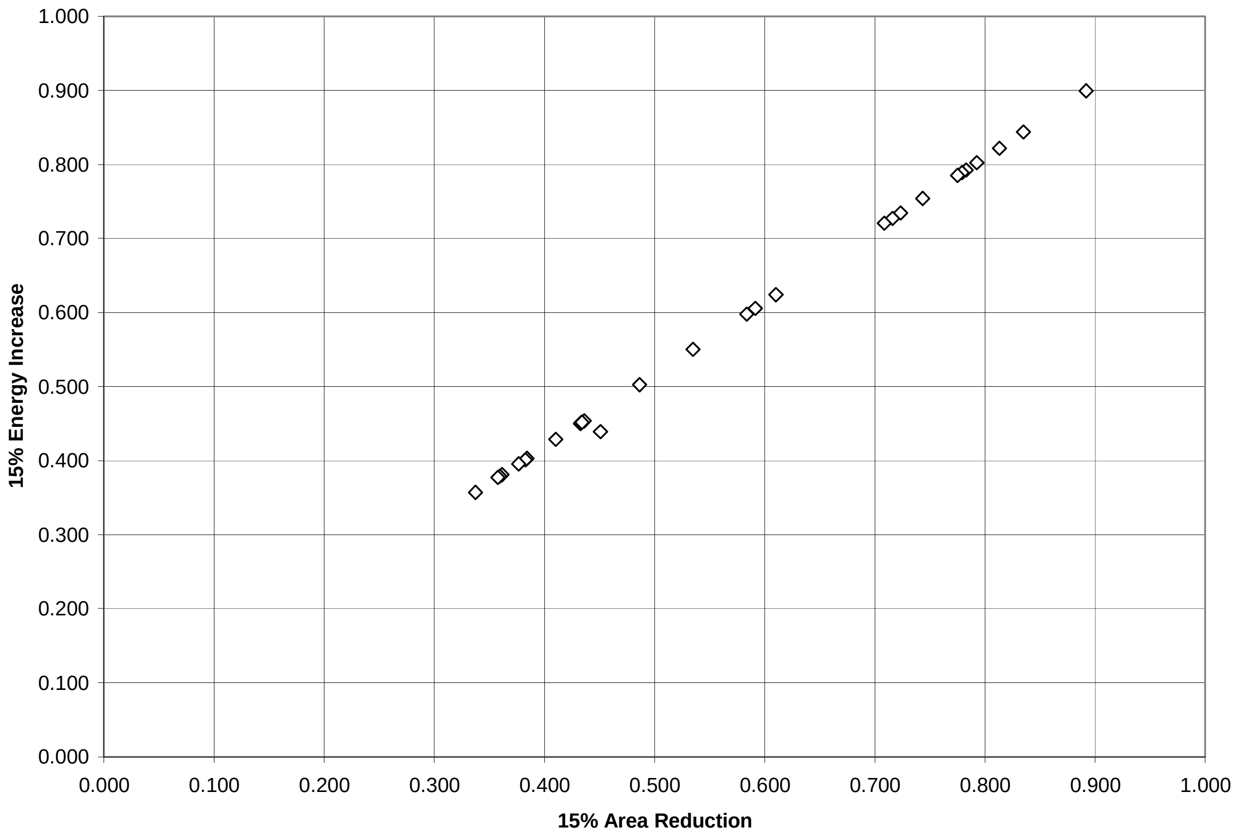
Due to the linear position in the bar being the source of the rating for ENERGYguide, the position of the rated building is exactly centered when comparing to the range of plus 15 percent and minus 15 percent of the energy, as shown in Figure 56 below. On the graph, the box represents the baseline rating while the top and bottom of the line represent the ratings at the 15% less and 15% more energy consumption. This approach of placement between the maximum and minimum creates an intuitive result when looking at the impact of energy consumption since the building consuming more or less energy affects the rating the same way. The overall impact on schools is the smallest with the shortest bars. Hospitals and offices appear to have roughly the same range.

Figure 56 – ENERGYguide Ratings with Plus and Minus 15% Energy Consumption



The energy intensity when reducing the floor area by 15% is very close to the energy intensity when increasing the energy intensity by 15%. The results of rating the building using ENERGYguide for those two cases are shown in Figure 57. Both axes represent ratings with the X-axis being the rating with 15% smaller floor area and the Y-axis being the rating with 15% more energy consumption. Here again, the linear relationship between the energy use and the resulting rating makes this a nearly straight line with an R^2 of 0.999.

Figure 57 –Reducing Area by 15% Compared to Increasing Energy by 15% in ENERGYguide

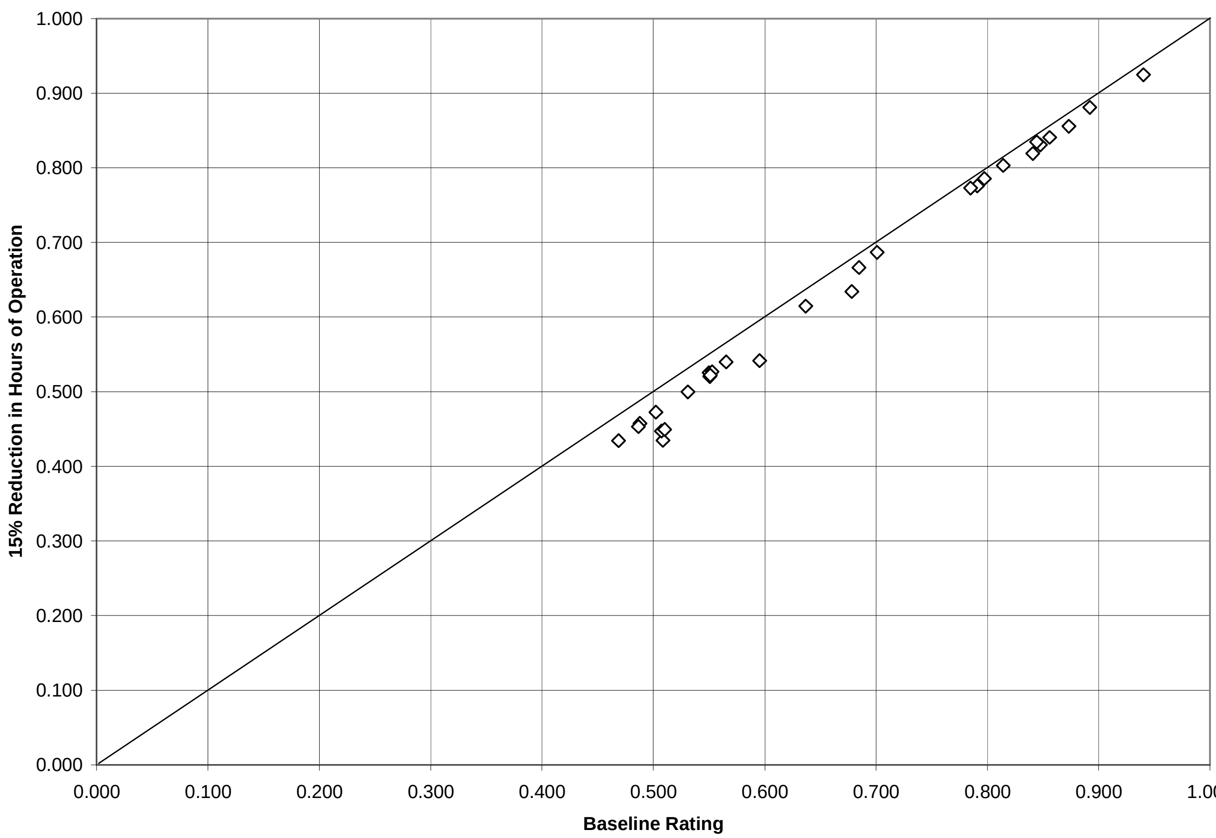


By reducing the number of operating hours by 15%, the ratings are consistently decreased as shown below in Figure 58 where both axes represent ratings. The hours were reduced by computing the total time from opening to closing each day, reducing that number by 15%, and allocating those hours over the days of operation. Normally, the same days of the week were used as the original hours of operation but for some buildings a weekend day was eliminated. Since the energy consumption, floor area and other parameters are fixed except for the reduction in the number of operating hours, the decrease in the rating is logical. The impact is small and decreases with increasing rating. The model for the relationship between the baseline rating and the rating with a 15% reduction in operating hours is shown in the following equation. The R^2 for this model is very high at 0.99.

$$y = 1.0736x - 0.0767$$

The figure below also includes a line representing no impact between the two parameters. For hospitals, the average rating dropped 6%, for offices, the reduction was on average 3% and for schools it was 1%.

Figure 58 – Ratings when Reducing Operating Hours by 15% in ENERGYguide



The four buildings chosen to test inputs that were unique to ENERGYguide:

- H-070
- L-021
- O-050
- S-098

These four buildings were used to test many of the inputs. In several cases the inputs did not make any difference at all:

- Age of building

- Number of floors
- Do you own or rent this property.

Why would inputs be required from the user when they do not appear to impact the results? Perhaps to match the user expectation of what is an important input and thus increasing the confidence in the rating method. In general, since each input adds a burden to the user entry process, the number of inputs should be minimized to minimize user input effort.

Several inputs showed no impact for specific building types.

- Business type for lodging
- Cooking energy source for office and hospital
- Business type medical clinic versus dental clinic
- Business type medical office versus dental office.

The following discussion of the impacts of the remaining inputs proceeds in the order that appears on the ENERGYguide web pages. The first input is "Business Type" which was varied for hospital buildings and for lodging. For lodging the four options were:

- Hotel
- Hotel with Restaurant
- Motel
- Motel with Restaurant.

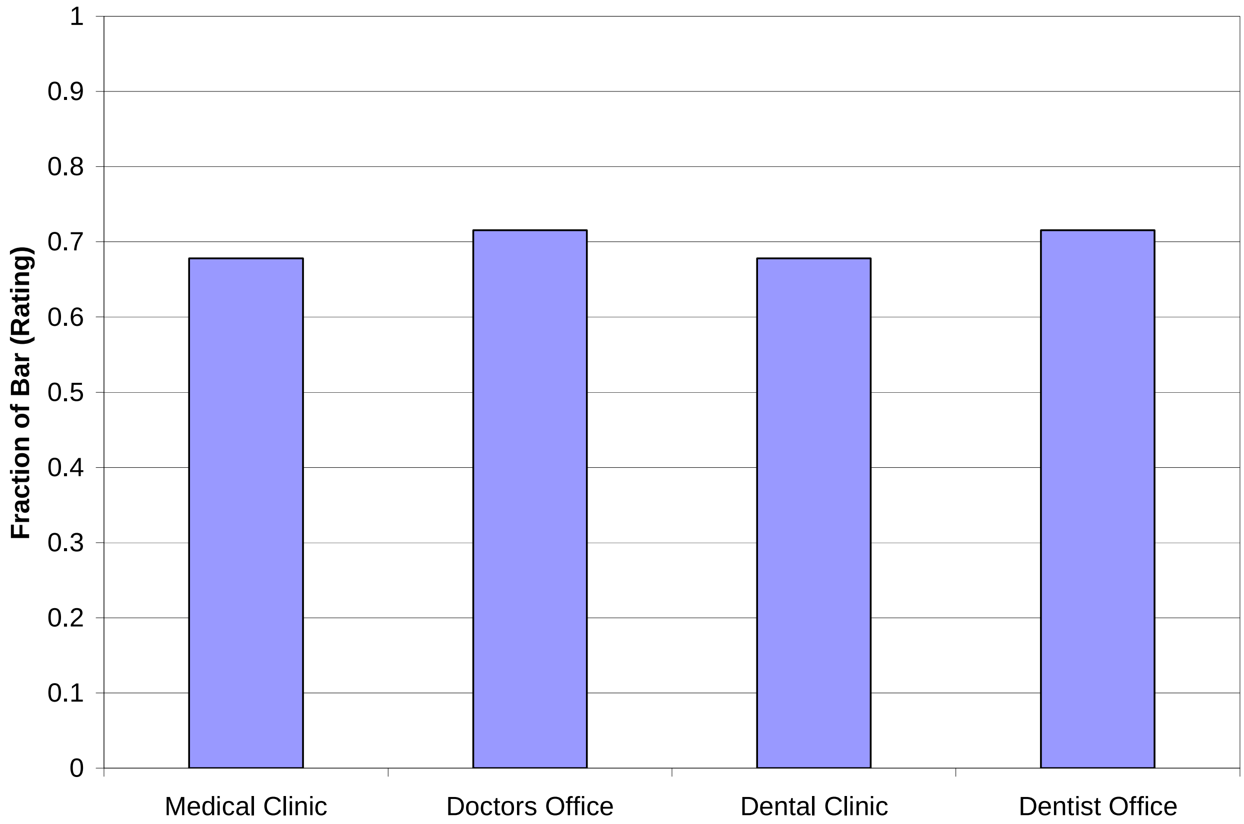
The selection of these options did not affect the resulting rating.

No option called 'hospital' was available in ENERGYguide so instead the following options were explored:

- Medical clinic
- Doctors office
- Dental clinic
- Dentist office.

The medical clinic option was used as the baseline. Figure 59 shows the impact of the choosing these different medical building options. The dental and the medical clinics have exactly the same rating which is 3.5% lower than the medical office building or dental office building. This is not an intuitive result since one would expect a clinic with more diagnostic equipment would generally consume more energy.

Figure 59 – Ratings for Medical Building Choice in ENERGYguide

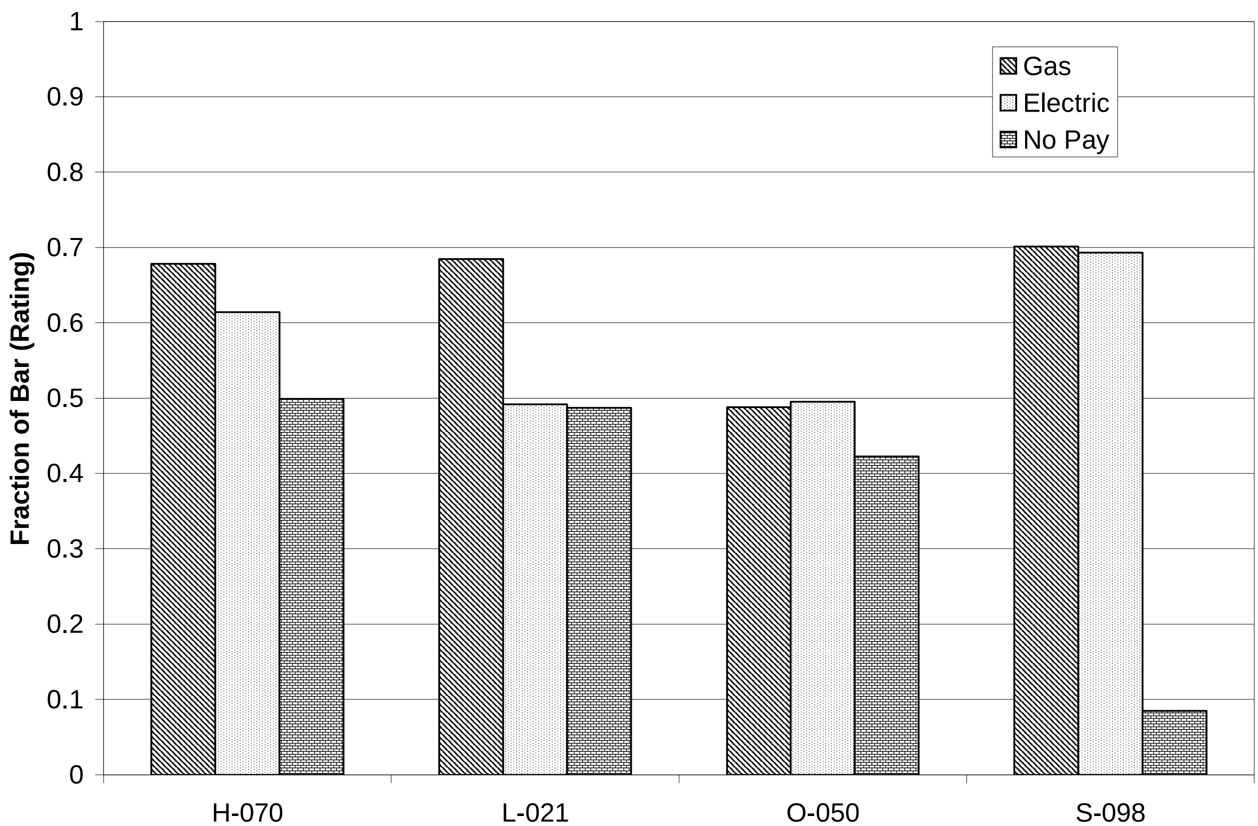


The energy sources for the different end-uses in a building were examined. The end-use choices include:

- Don’t have/don’t pay
- Electric
- Gas
- Propane
- Oil.

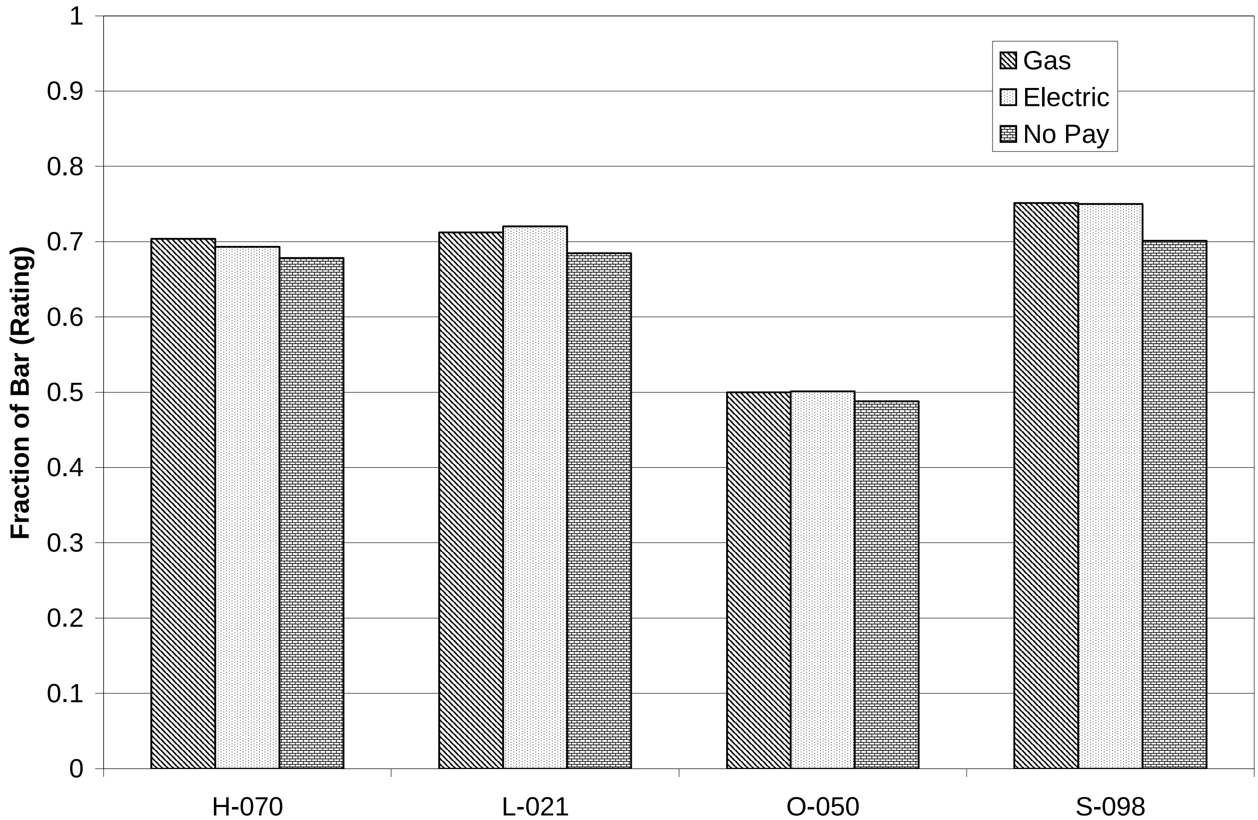
Primary and secondary heating allow these inputs along with water heating. Since they are more unusual in commercial buildings, propane and oil were not evaluated. The electric and gas consumption was not changed when performing these ratings. Figure 60 shows the results for heating end-use choice in ENERGYguide. In all cases, the baseline source of heating energy was natural gas. Lodging showed the largest change when switching the indicated source of heating energy. Office and schools had little impact when changing to electric heating. When the "Don't Have/Don't" pay option is chosen the ratings are all lower. This is because the energy consumed by gas for heating is now assumed to be used for other end-uses. For schools, the impact of this choice seems exaggerated with the rating going from about 70% to about 8%.

Figure 60 – Ratings for Heating End-use Choice in ENERGYguide



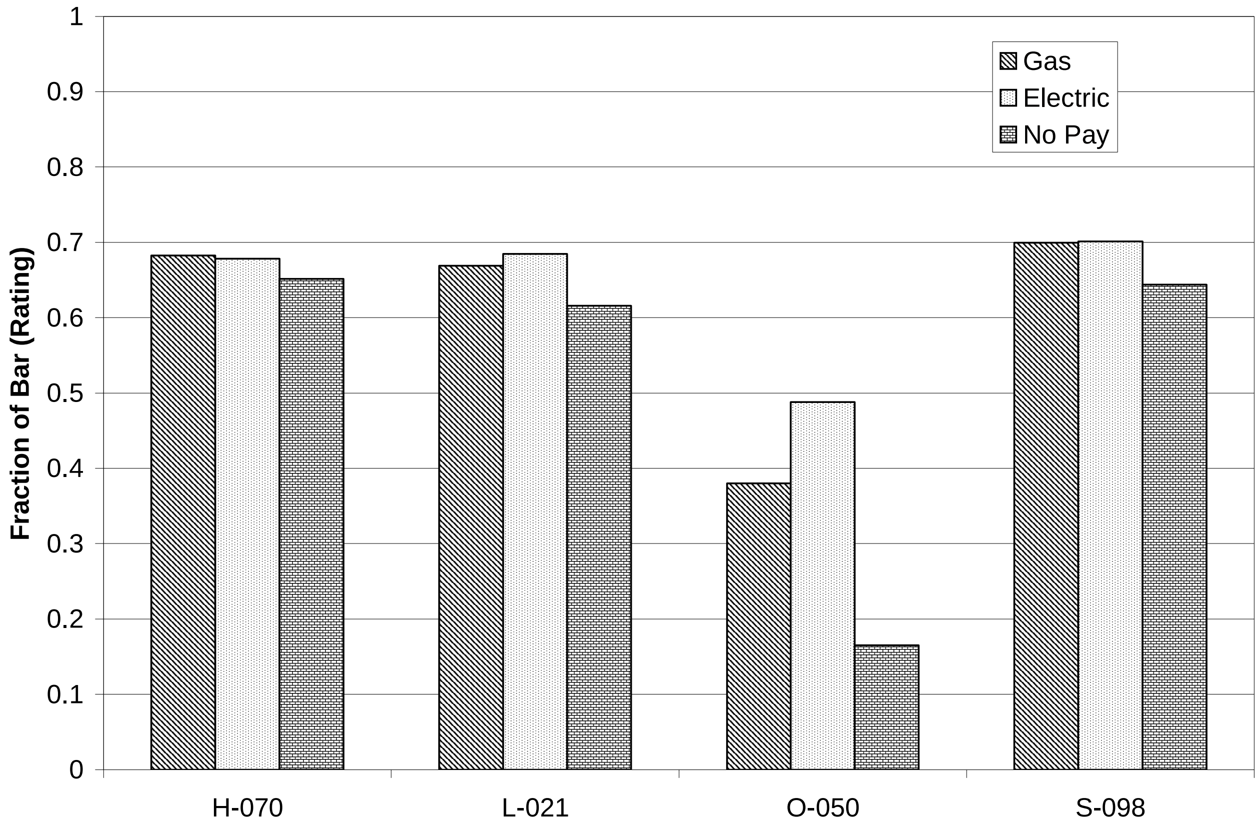
As expected the impact of changing the secondary heating source is significantly smaller across all building types as shown in Figure 61.

Figure 61 – Ratings for Secondary Heating End-use Choice in ENERGYguide



The following chart, Figure 62, shows the impact of the energy source choice on cooling end-use. For all buildings except the office, the impact of changing from electric (the baseline case used throughout the analysis) to gas was small. Changing to “not paying” reduced the rating some. The results for office building follow a similar pattern as the other building types but seems exaggerated. The database of buildings probably contains very few that use gas for cooling which calls into question the validity of these specific results.

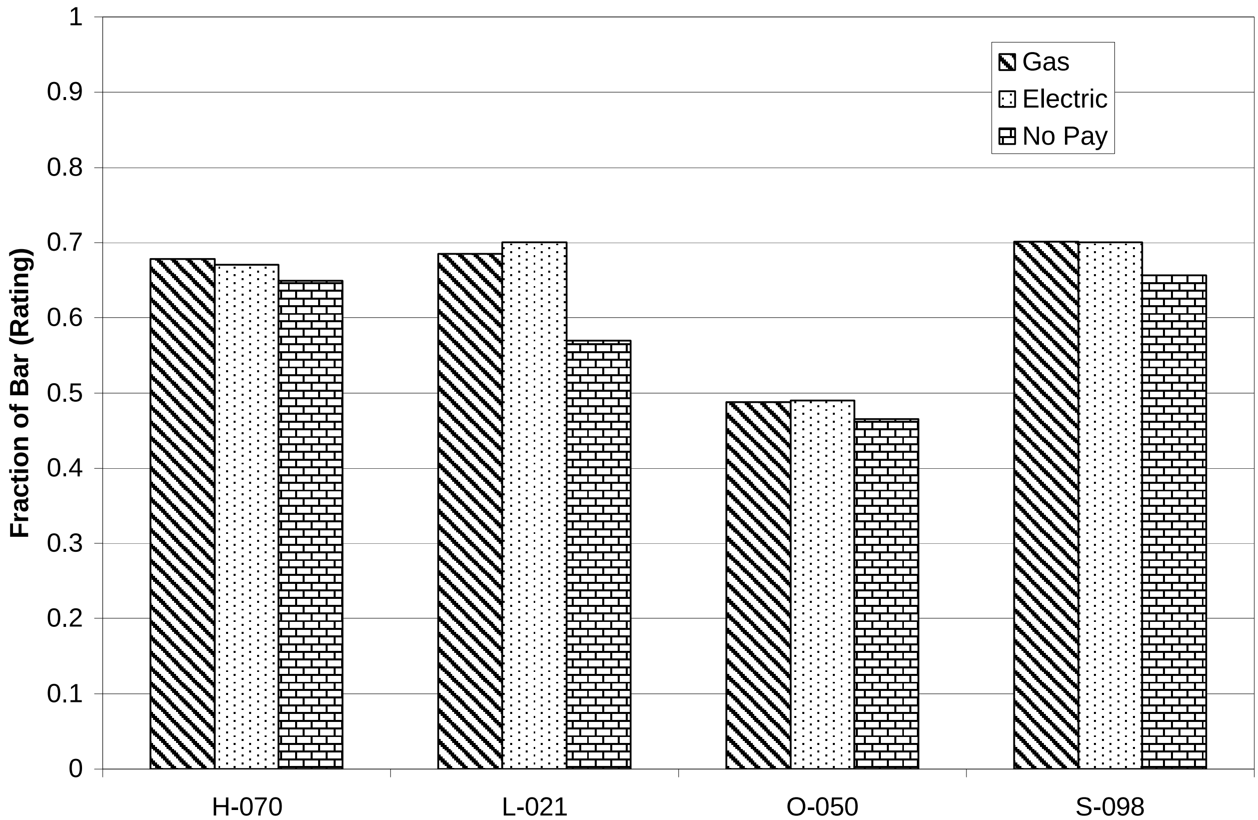
Figure 62 – Ratings for Primary Cooling End-use Choice in ENERGYguide



For secondary cooling, not shown, the impacts are similar but smaller. The largest impact is for office going from the No Pay to the Electric case where the rating increases by 4.2% while the other changes are 1.2% or smaller.

For the four selected buildings, the energy source used for service water heating was natural gas. Again, in all cases, the rating with the "No Pay" option was the lowest as seen in Figure 63. It was lower than gas by 2% (office) to 11% (lodging). The impact of specifying electricity as the source of energy for water heating instead of gas made a small impact on the rating of about 1% or less for all buildings.

Figure 63 – Ratings for Service Water Heating End-use Choice in ENERGYguide



The refrigeration end-use choices are "Electricity" or "Don't have/Don't pay". The buildings besides the school all had electric refrigeration. The impact of specifying, "Don't have/Don't pay" was a reduction in the rating for all the building types varying from 0.4% for hospital H-070 to 1.5% for lodging L-021.

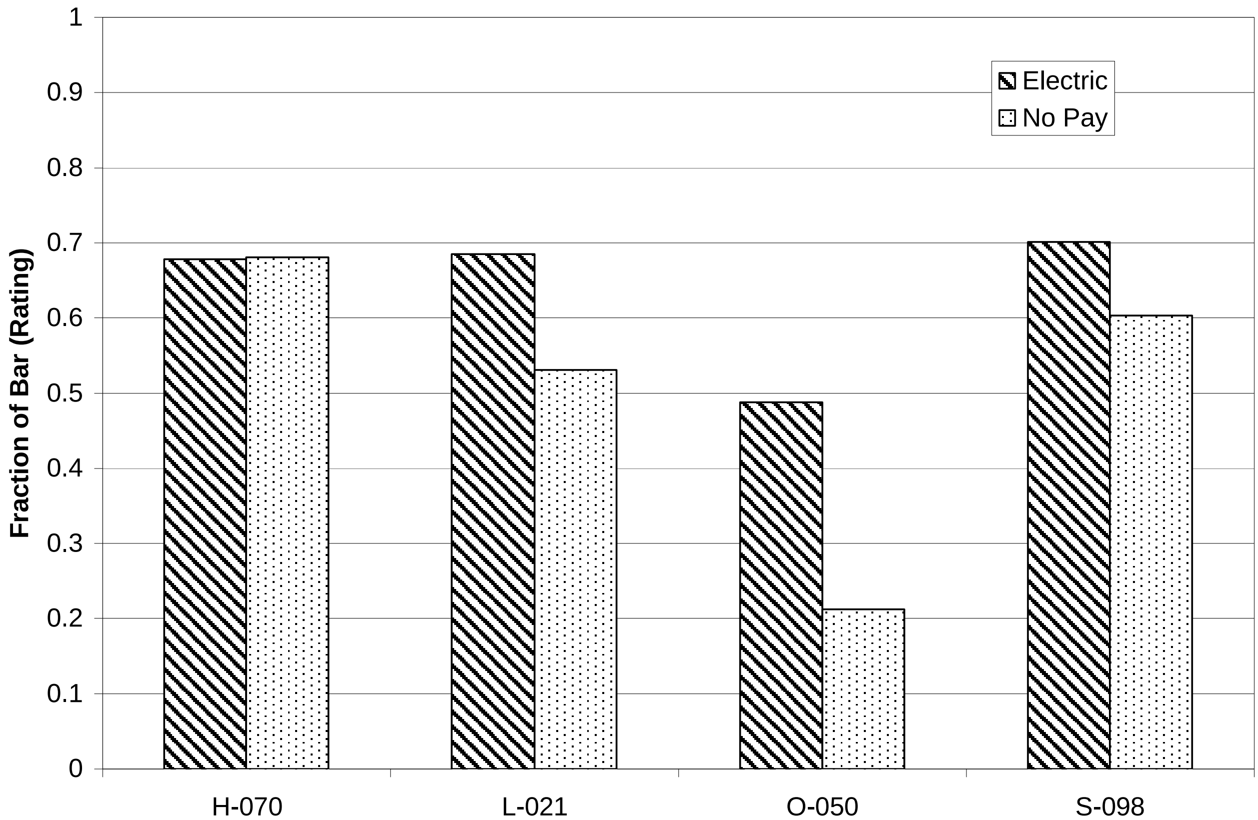
As previously mentioned, changing the cooking end-use showed no impact for the hospital and office buildings. This is logical since offices that are under 100,000 sqft very rarely have cooking facilities and the hospital building used the medical clinic building type that also very rarely has cooking facilities. The lodging and school buildings had minimal impact to changing between the electric and gas specification for the cooking end-use of 0.5% or less. Selecting "Don't have/Don't pay" decreased the rating about 1% compared to selecting natural gas.

For the laundry end-use, almost no impact was seen for the office building, O-050. For the school and hospital building, the change was about 1%, with selecting electricity resulting in the highest rating. Normally, hospital laundry is a more significant end-use but because the building types were limited to other types of medical buildings, such as a medical clinic, the impact is small. For lodging the impact was as large as expected with the highest rating for the electricity case at 72% followed by gas at 68% and finally the "Don't have/don't pay" case at 65%.

Interior lighting is one the largest end-uses for commercial buildings and the following figure, Figure 64, shows the significant impact of specifying, "Don't have/don't pay" for that end-use instead of electricity.

The impact for the hospital is much smaller than expected and is difficult to explain. The statistical model for hospital must not be very dependant on that variable. The other buildings show impacts of 10% to 28% that is reasonable given the large fraction of the total building energy use that is for interior lighting.

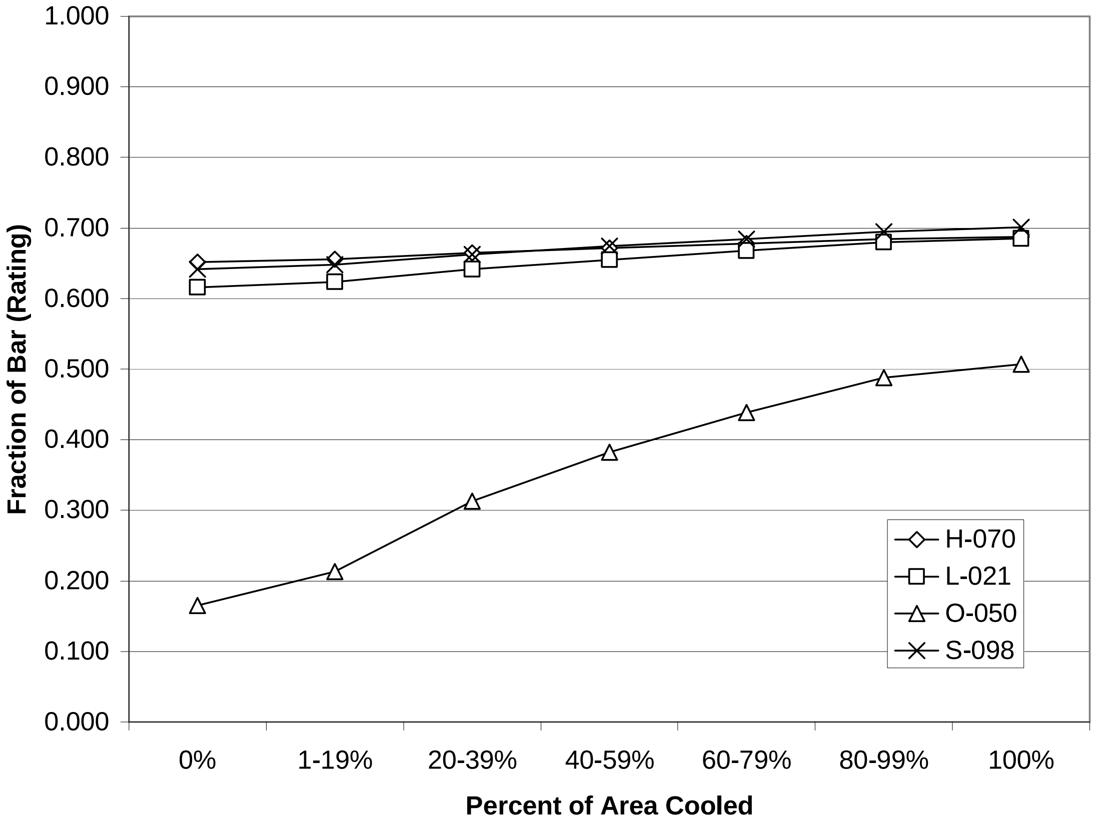
Figure 64 – Ratings for Interior Lighting End-use Choice in ENERGYguide



For exterior lighting, the four buildings showed a decrease of 1% to 2%.

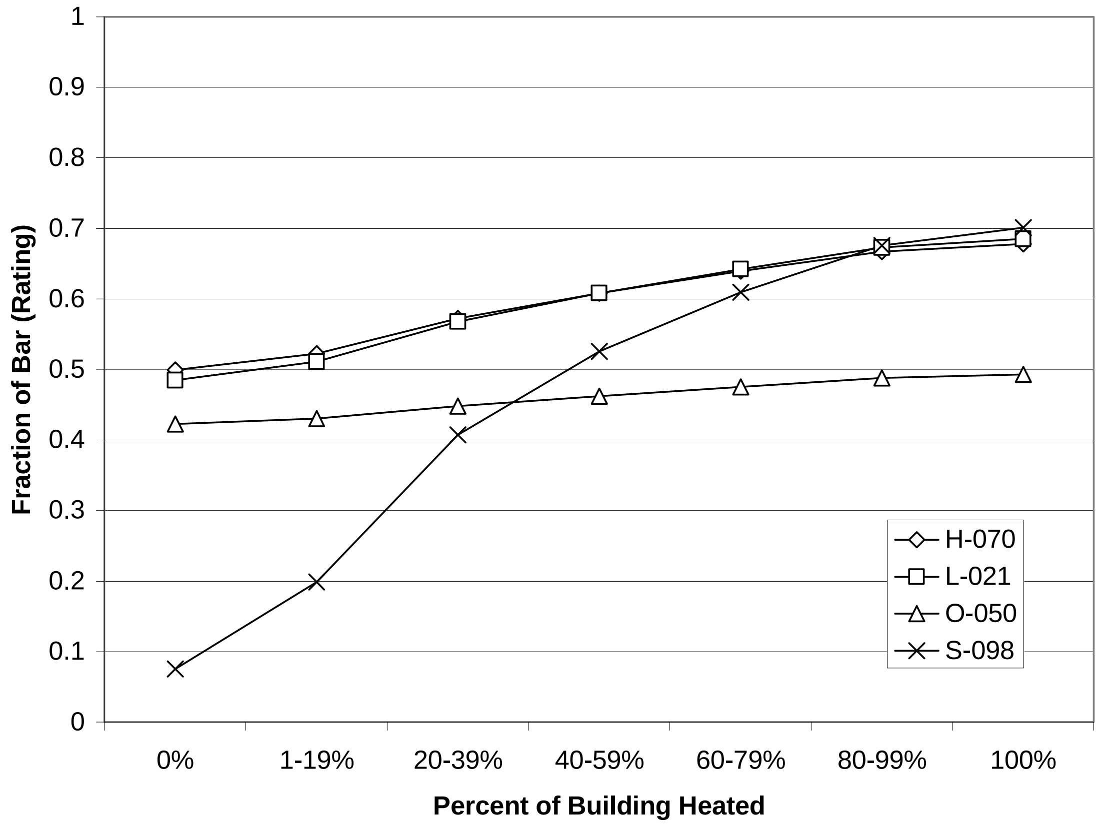
The impact of the "What percent of the total area is cooled" input is shown in Figure 65. All buildings had the same trend of increasing rating with an increase in the fraction of the building area that is cooled. The office building showed a very large impact from changing this input from 16% to 50%. Office buildings are often driven by high internal loads that result in high cooling loads. The other buildings vary a much smaller amount increasing from 4% to 7% in the rating from 0% cooled to 100% cooled.

Figure 65 – Ratings for Percent of Area Cooled Choice in ENERGYguide



The impact of the "What percent of the total area is heated" input is shown in Figure 66, and is very similar to the percent cooled graph previously discussed. Again, all buildings had the same trend of increasing rating with an increase in the fraction of the building area that is heated. For heating, the school building showed a very large impact from changing this input from 8% to 70% as the percentage of the building heating went from 0% to 100%. Schools are often dominated by heating loads, especially for those that don't operate in the summer. The other buildings vary a much smaller but very significant amount increasing from 7% to 20% in the rating from 0% to 100% heated.

Figure 66 – Ratings for Percent of Area Heated Choice in ENERGYguide

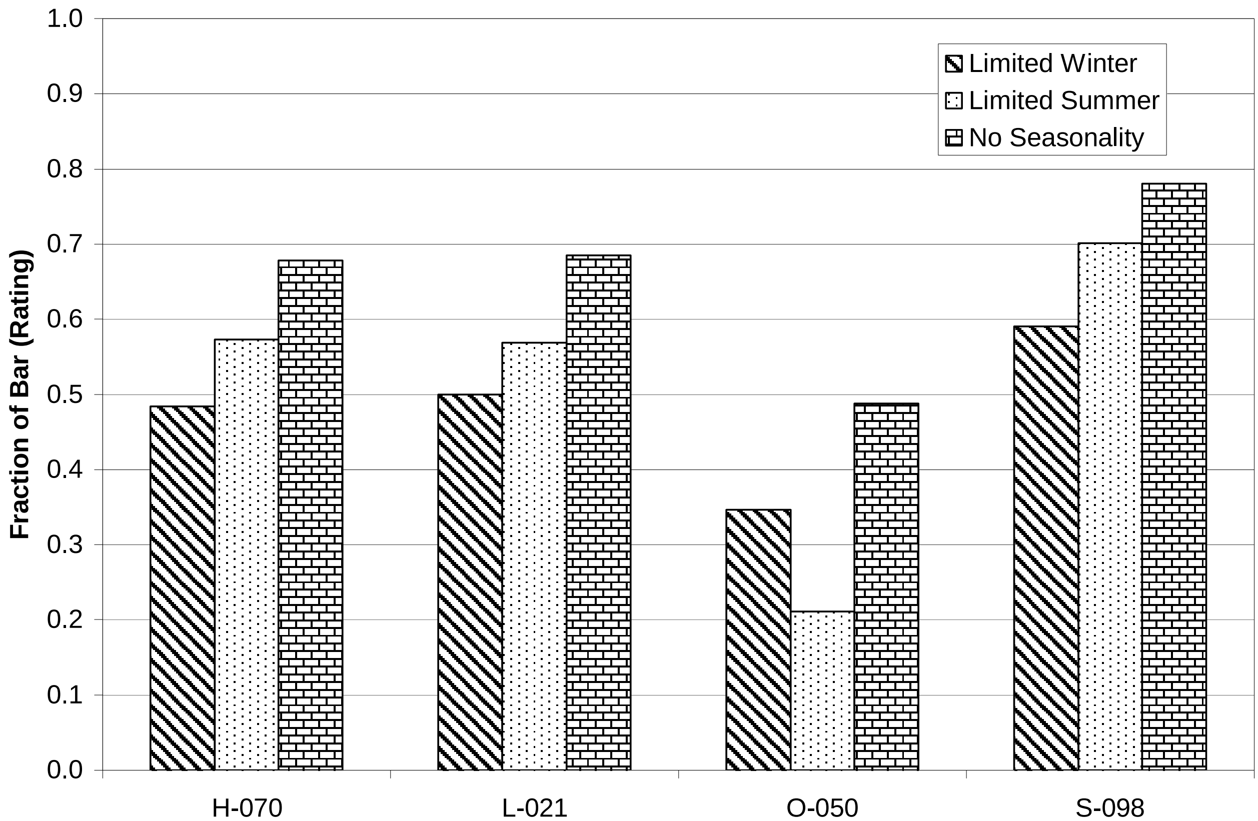


The user has three options for the parameter "Is there a seasonal nature to your operation" which are:

- No. Operations are consistent all year
- Closed or limited operations in summer
- Closed or limited operations in winter.

For the four building types used in this report, only schools commonly have any seasonality to their operation. Some lodging, near seasonal recreation areas such as skiing, may also operate seasonally. Given this, the seasonality choice impacts seem very large for hotel and office, see Figure 67. Generally, the impact of going to limited winter option was 14% to 19% and the impact of limited summer operation was 8% to 11% not including office building that changed 28%.

Figure 67 – Ratings for Seasonal Operation Choice in ENERGYguide



8.6 Supplementary Buildings

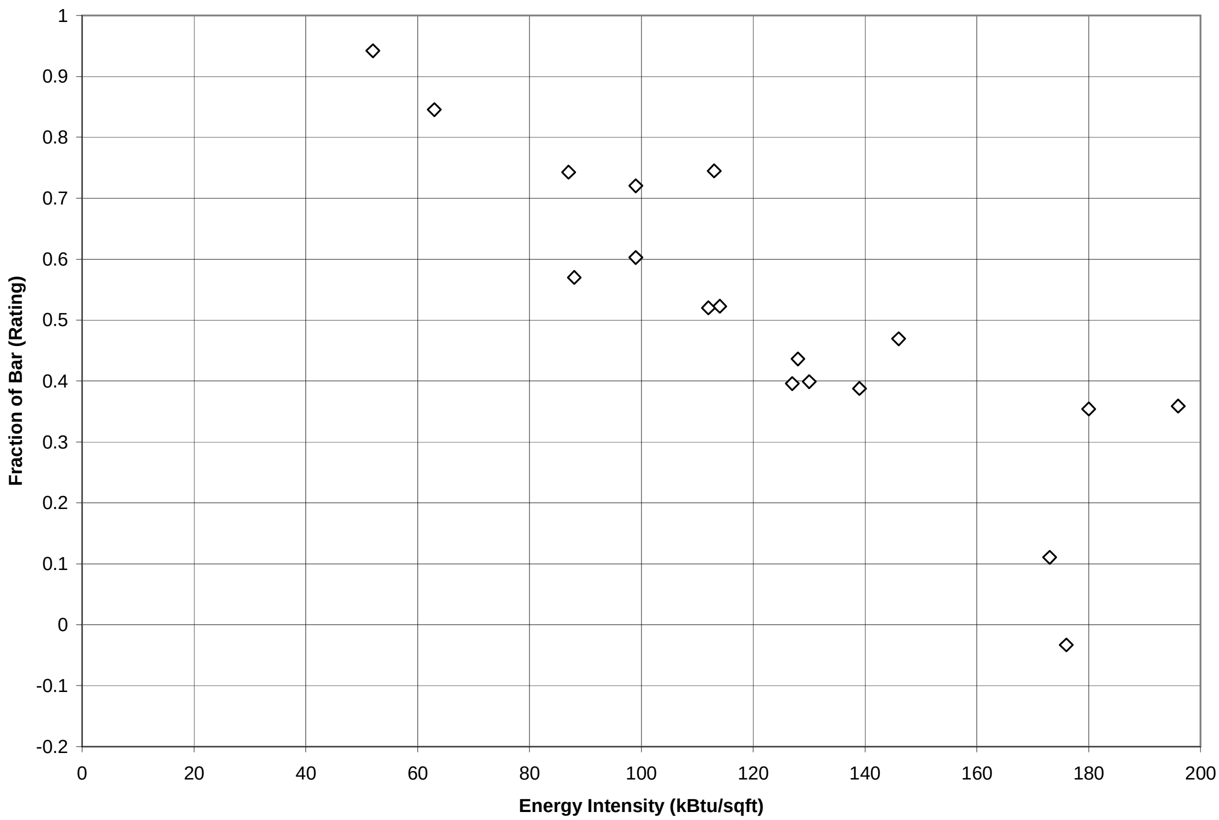
As with the other rating methods, 167 selected buildings from the North West Energy Efficiency Alliance's Commercial Building Stock Assessment were rated with ENERGYguide. Performing ratings with this broad range of buildings uncovered examples of ratings that both exceed the upper end of the ENERGYguide bar maximum and are below the ENERGYguide minimum. Two buildings had lower energy expenditures than the ENERGYguide minimum by 12% or less. On the other end of the scale, 18 buildings exceeded the maximum energy expenditures with three of those by more than double.

Figure 68 shows the school buildings rated using ENERGYguide and show a good correlation with energy intensity. One school is excluded from the graph because its energy intensity is over 550 kBtuh/sqft, clearly an outlier for schools. The following equation fits this data with an R^2 of 0.81.

$$y = -0.0054x + 1.1774$$

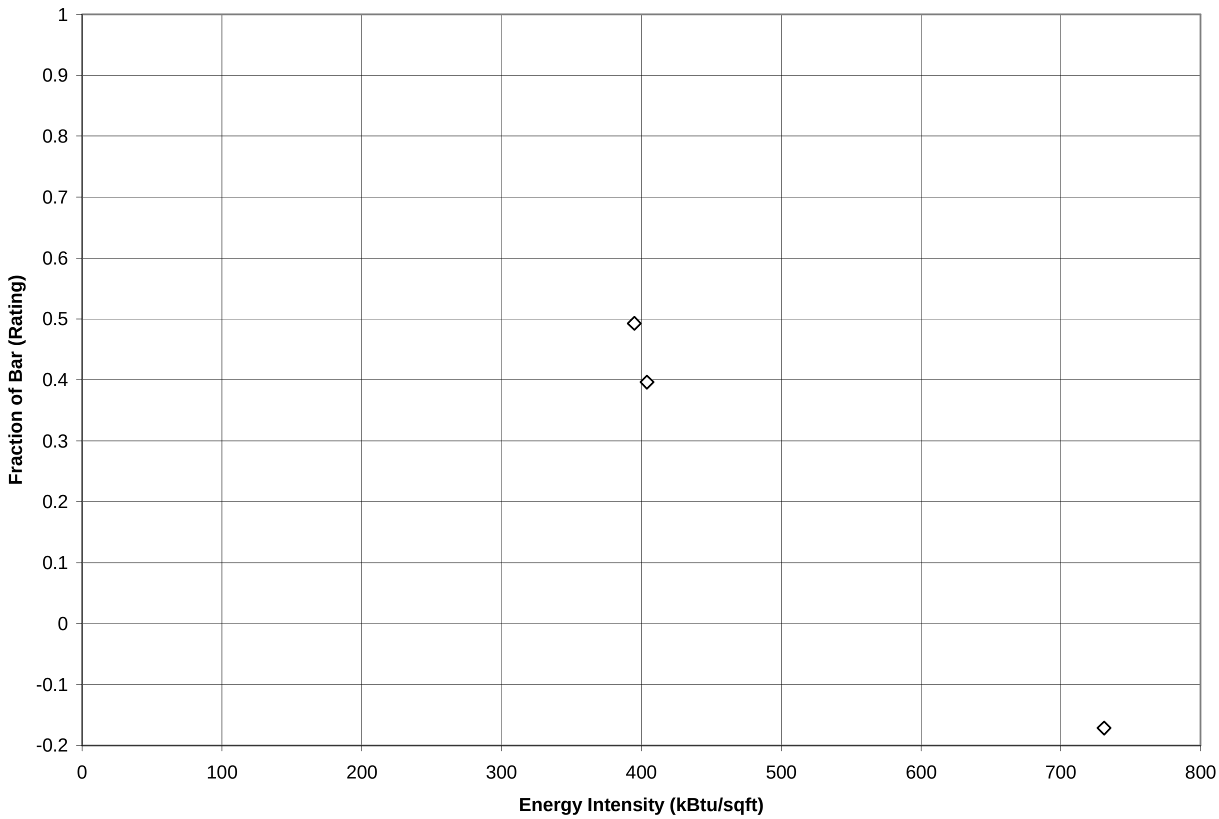
The zero energy building can be thought of as the Y-intercept and has a value of 1.1774, somewhat above unity. The X-intercept represents a building as poor as the rating system would rate, 218 kBtu/sqft.

Figure 68 – Supplementary Schools Rated in ENERGYguide



For hospitals, the supplemental database only contains three buildings so few conclusions can be drawn especially with two of the points so close although the general trend of better rating with lower energy intensity is as expected, see Figure 69.

Figure 69 – Supplementary Hospitals Rated in ENERGYguide

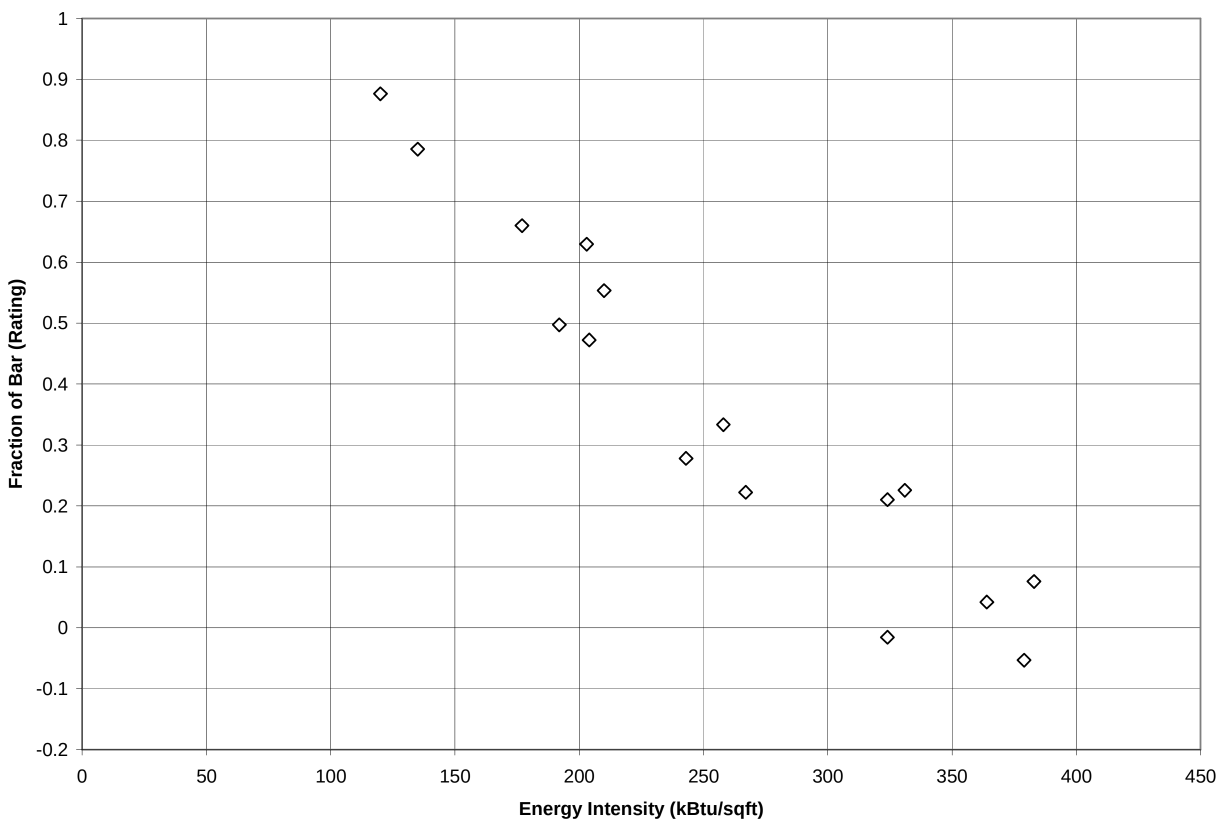


The sixteen hotels or motels in the supplemental database are shown in Figure 70 plotted against energy intensity. The hotels appear to be in a single group unlike how they appeared in a similar graph using Arch. The linear regression model for the hotels has an R^2 of 0.91 and is:

$$y = -0.0032x + 1.1884$$

This again shows a Y-intercept of 1.19 corresponding to the rating a zero energy building would receive. This going above the upper limit would be confusing to someone rating a building that is a very low energy building. The X-intercept of 371 kBtu/sqft is the intensity for the lowest possible rating a hotel or motel could receive.

Figure 70 – Supplementary Hotels/Motels Rated in ENERGYguide

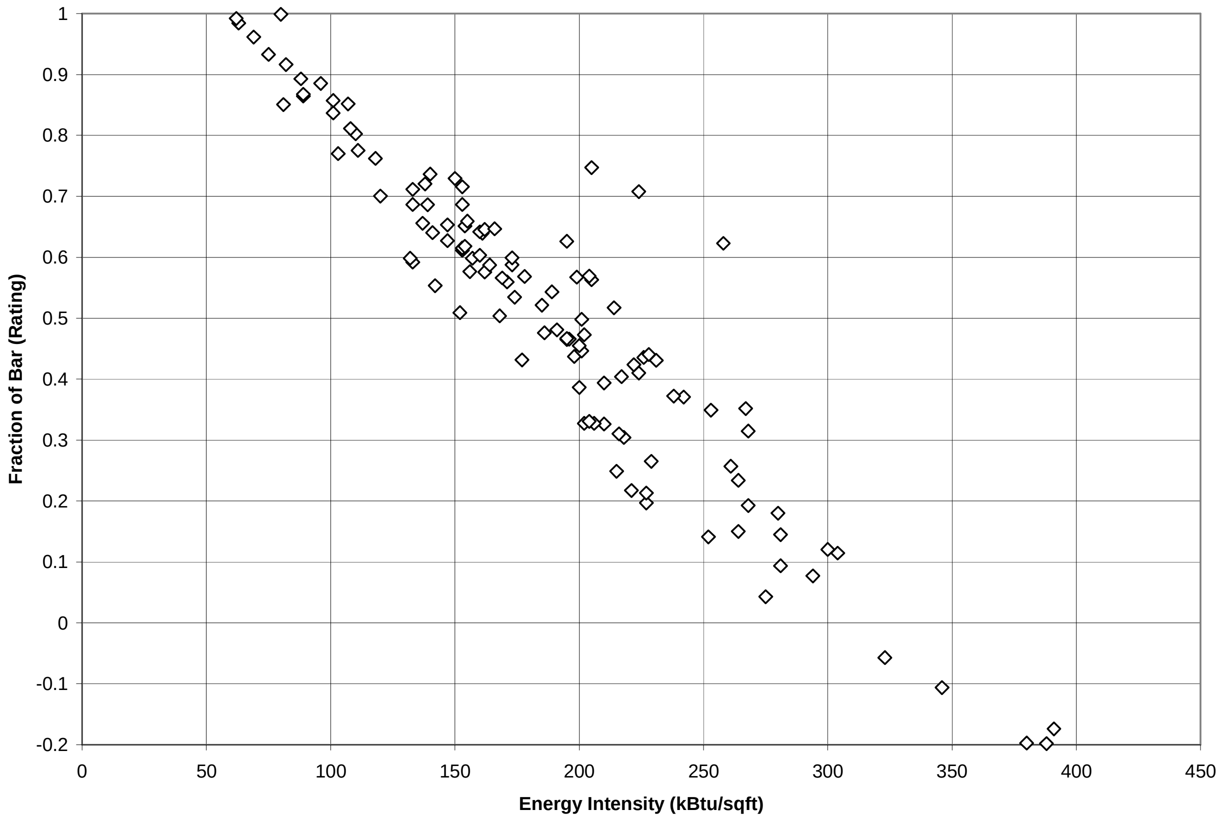


Office buildings are the most numerous type of building in the supplemental data set. Figure 71 shows all buildings with ratings above –0.2. This graph also shows a very strong linear correlation. Using linear regression, a simple model was developed.

$$y = -0.0037x + 1.1996$$

This model has an R^2 of 0.89 so it is a good fit for the data. Similar to other building types the Y-intercept that corresponds to a net zero energy building is about 20% beyond the range of the rating bar. The X-intercept is 324 kBtu/sqft and is the maximum annual energy use that would still be on the rating scale.

Figure 71 – Supplementary Office Buildings Rated in ENERGYguide



8.7 Discussion

The following conclusions may be drawn from the rating analysis performed using ENERGYguide on the 29 primary buildings:

- The position of the pointer on the result bar graph is based on the linear position for the value between the minimum and maximum of similar facilities shown.
- The maximum size for a building being rated by ENERGYguide is 99,999 square feet. For the analysis, buildings larger than this size were scaled down.
- The average rating for schools was 82%, followed by office at 60% and hospitals at 57%.
- The broadest range of ratings was for offices at 42% followed by schools at 24% and hospitals at 17%.

- When cooling and heating dominated climates were substituted, the ratings for schools changed the most with an average of 11% while hospitals and offices changed by 5% and 3%, respectively.
- The linear nature of the rating resulted in the change due to 15% increase or decrease in energy consumption being approximately the same magnitude for all buildings. Schools changed less than hospitals and offices.
- The ratings for buildings with the same energy intensity but reduced area were nearly unchanged.
- The ratings for the buildings with operating hours per week reduced by 15% were consistently lower by an average of 6% for hospitals, 3% for offices, and 1% for schools.
- The inputs for the age of building, the number of floors, if the building was occupied by owners or renters, the lodging building subtype, cooking in offices and hospitals, and some of the medical building subtypes had no impact on the rating.
- Unintuitively, the medical and dental clinics rate 3.5% lower than the medical and dental offices.

Four buildings were chosen, one of each from hospital, lodging, office and school to evaluate some of the inputs. The following conclusions can be drawn.

- When the primary heating energy source was changed to none, the ratings were consistently lower and when the secondary heating energy source was changed to none the ratings were also lower but by a much smaller amount.
- When the primary cooling energy source was changed from electric to gas for the hospital, lodging and school buildings this did not substantially affect the rating. The rating for the office when using gas cooling was about 10% higher.
- When the secondary cooling energy source was changed, the rating changed by only 1% on average.
- Specifying electricity as the source of water heating energy instead of gas changed the rating by 1% or less but changing the source to none, lowered the rating for the office by 2% and for the lodging building by 11%.
- Refrigeration, cooking and exterior lighting for all four buildings had minimal or no impact on the ratings.
- Laundry had almost no impact except for the lodging building.
- When interior lighting was changed to “don’t pay” the lodging, office and school buildings changed by 10% to 28%. Unintuitively, the rating on the hospital building did not show much change.
- When the stated fraction of the building that was air-conditioned was changed from 0% to 100% the ratings continuously improved. The improvement was 4% to 7% for the hospital, school and lodging but improved 34% for the office building.
- When the stated fraction of the building that was heated was changed from 0% to 100% the ratings continuously improved. The improvement was 7% for the office building, 20% for the hospital and lodging buildings, and 62% for the school.
- Choosing operation that was seasonal reduces the ratings of all buildings. Going to limited winter operation dropped the ratings 14% to 19% and going to limited summer operation reduced the rating about 10% except for offices that was almost 30%.

The following conclusions may be drawn from the analysis of the 167 supplementary buildings with ENERGYguide:

- Not enough hospital buildings were present to draw conclusions.

- Schools, lodging and office buildings showed a linear relationship between the increasing ratings and the decreasing energy intensity with some scatter.
- The y-intercept representing the rating for a building with zero energy intensity was above 1.0 for schools, lodging and office buildings.
- The x-intercept representing the energy intensity for a building with a zero rating was 218 kBtu/sqft, for schools, 371 kBtu/sqft for lodging, and 324 kBtu/sqft for offices.

One of the strengths of ENERGYguide is the simple output of a pointer for the annual energy cost of the rated building on a bar graph between the minimum and maximum buildings. This is easy to understand and matches similar graphs used in other energy performance labeling for appliances. One draw back to this approach is when a building appears beyond the range of the graph at either the minimum or maximum side of the bar. Perhaps a description of the issue and the meaning should appear instead of, or along with, the graph.

The ENERGYguide web site allows multiple buildings to be described so that a building manager with a portfolio of buildings can have ratings on all of them. Unfortunately, it does not have any way of uploading data for multiple buildings at a time or to download all of the results or input details at once. This lack of processing groups of buildings together was especially difficult during the analysis but would also pose a barrier for those with especially large portfolios of buildings.

As previously mentioned, some inputs do not affect the resulting rating such as the own/rent question, number of floors, age of building, and some of the building subtypes. This serves to confuse users and increase the effort needed to enter a building into the web based system.

The input system for a building has a few unusual issues that may not affect many users but should still be reconsidered.

- The energy price entered by the user should be rounded to display more significant digits. Many rates show prices to more digits.
- When entering electricity that is close to the “model estimate” it will continue to be reported as the “model estimate” even when it is entered by the user.
- The buildings can only be 99,999 sqft or smaller. This is not described anywhere on the web site and is a limit that is eliminating many buildings seeking a rating.
- The identification of the source of energy by end-use is not always understood by building operators or managers.
- No way to delete a building from the group of buildings described.

Finally, the most serious draw back is to ENERGYguide is probably the lack of public information about how it works and the algorithm behind it. The disclosure of the algorithm allows experts to conclusively state whether the rating system is valid and, without that, some users may be concerned with the results.

9 Comparison and Conclusion

The five protocols described in the previous sections each have strengths and weaknesses. One way to understand them is to compare and contrast the protocols with each other. The following section does not endorse or recommend any protocol but instead evaluates each protocol within the context of different criteria.

Several papers were reviewed to understand different areas that could be compared. In an evaluation of different assessment methods for British Columbia (Cole 2001) the following areas were described as part of an ideal method:

- Simple and practical
- Inexpensive
- Transparent
- Credible
- Challenging
- Covers essential environmental and resource issues
- Versatile
- Offers multiple ways to communicate results
- Globally applicable, yet regionally specific
- Capable of evolving
- Encourages innovation
- Useful as a design tool
- Educational

In another source looking at choosing a method for South Africa (Kaatz 2002) lists:

- Comprehensiveness
- Effectiveness
- Adaptability
- Flexibility
- Practicality and cost
- Accessibility
- Integration
- Consistency

Other areas to evaluate rating protocols, include:

- Building type flexibility
- Empirical Basis
- Special use areas in buildings
- Monitoring of building use over time
- Suggested next steps
- Part of certification
- Ease of understanding results

Overall, most of the areas for evaluation described above can be put into the following seven broad categories that will be the remaining sub-sections of this report.

- Scope of Application
- Empirical Basis
- Input Requirements
- Output and Transparency
- Part of Certification Process

- Effort and Expense
- Influences Design or Retrofit

Finally, the last subsection contains specific conclusions.

9.1 Scope of Application

LEED-NC and LEED-EB may be applied to any commercial building regardless of the type of building. Some of the credits are most appropriate for an office building but certification can still be sought by any commercial building. One of the main energy related credits in LEED is Energy and Atmosphere Credit 1. This credit offers few restrictions in LEED-NC since it relies on ASHRAE 90.1-1999 Energy Cost Budget section that is a general simulation based approach. The same credit for LEED-EB uses ENERGY STAR Label for Buildings that has a specific list of buildings that may be evaluated but the credit also allows any other building to use a method that is similar to the method used in ENERGY STAR Label for Buildings. This option is probably too onerous for many to pursue. The lack of retail buildings in ENERGY STAR Label for Buildings is likely to keep that type of building from obtaining LEED-EB ratings. There is an implied lower limit on building size for LEED due to the effort and cost of the LEED process, so it is unlikely that many smaller buildings would seek to obtain certification and in fact, the average size of a building seeking certification under LEED is over 120,000 square feet.

BREEAM and ENERGY STAR Label for Buildings both apply to only a specific list of buildings and have taken the approach of developing a custom version for each major building type. This may result in fewer buildings that can be certified under each method but those methods will probably be more accurate and better tailored to those buildings. BREEAM, like LEED, requires a significant investment in time and money and is unlikely to be applied to smaller buildings.

Arch, Cal-Arch and ENERGYguide each apply to almost all commercial buildings since they are based on broad commercial building surveys (CBECS and CEUS) using a general algorithm that is used by all buildings. In addition, these protocols are web based and available for no charge, encouraging use by large and small buildings alike. ENERGY STAR Label for Buildings applies to only some of the most common building types and has a lower cost to obtain certification than LEED or BREEAM. In addition, ENERGY STAR has minimum sizes that exclude very small buildings.

The ENERGY STAR protocol has specific allowances for space types in addition to using an overall building type. Because the LEED-NC energy credit uses ASHRAE Standard 90.1, specific space types are able to be specified. All of the other protocols ignore the variation in space types in the building. LEED-NC would probably be best suited for the many multi-use buildings built today.

Geographically, none of the protocols is intended to be used globally. LEED-NC has been applied in other countries but relies on many ASHRAE Standards that are mainly used in the U.S. Cal-Arch is intended to be used in California only. BREEAM was intended for use in the United Kingdom but has been applied to other countries. The remaining protocols are intended to be used in the United States. All of the protocols may be used outside their intended locations but their accuracy and applicability would be diminished.

Overall, point based methods, due to their high cost and effort of obtaining certification, are the most likely to discourage use by smaller buildings. The high cost of rating is often due to including non-energy points in methods such as LEED and BREEAM. The number of building types is most likely to be limited by a development philosophy of customizing the rating system for each building type as in BREEAM and ENERGY STAR. A possible compromise is to develop first a general methodology that applies to all buildings and then work on refining the rating system for specific building types. Offering the rating system at no charge or at low cost is likely to be the best way to encourage its use by smaller buildings. Any rating system developed today should consider allowing multiple uses to be specified in the same building. A protocol that was specifically designed to be used globally may also enjoy widespread use especially by multinational corporations.

9.2 Empirical Basis

Arch, Cal-Arch, ENERGYguide, ENERGY STAR, and LEED-EB are all based on databases. Cal-Arch uses the CEUS database while the others use the CBECS database (ENERGY STAR also uses two other private databases for certain buildings). CEUS is based on on-site visits while CBECS is a phone-based survey. The data filtering and statistical methods described in the ENERGY STAR documentation is exemplary and should be used as an example of the level of detail that should be disclosed publicly for all building energy rating protocols. It is difficult to compare the specific data filtering methods used in these protocols because they are not all documented in great detail. Filtering survey records based only on graphical methods, as used by ENERGYguide, runs the risk of narrowing the overall range of data. The extra smoothing steps employed by ENERGY STAR also may alter the distribution of buildings being represented at the expense of making the output more consistent and easier to understand. The use of alternatives to the CBECS database for Hospitals and Hotels by ENERGY STAR suggests that for those two building types, the use of CBECS data by the other protocols may be suspect.

BREEAM uses a threshold for energy use that is based on a sample of buildings but it is clear that it was not developed based on a statistical method. For design, BREEAM uses no empirical data at all and uses a simulation-based approach similar to LEED-NC.

LEED-NC does not utilize empirical data since it is intended to be used during the design stage of a building prior to when actual energy consumption is known. Since many decisions that may affect building energy use are made during design, this type of benchmark may be able to cause greater building-level reductions in energy use compared to those that are based on empirical data. Of course, the number of new buildings is small compared to the number of existing buildings.

The use of empirical data as a source for comparison in an energy rating protocol provides a sense of reality by comparing to real buildings. Unfortunately, no survey is large enough to allow comparing the rated building only to buildings that match it precisely. Instead, buildings are compared to a variety of buildings from the database that match major parameters such as building type and location or a multiple linear regression technique is employed to create a model of the range of buildings.

It is also difficult to know where a minimally energy code compliant building will fall in the range of buildings in an existing database. Energy codes, such as the IECC (ICC 2006) and ASHRAE Standard 90.1, change every few years so it may be difficult to keep up with that speed of change. For new construction, it would be best if the building that just complied with the energy code were not misclassified as an exemplary building by a rating protocol. Instead, a code compliant building should earn a “C” grade, just passing the requirements but not being perceived as outstanding.

Given how difficult it is to obtain an accurate measure of floor area, it is recommended that future protocols attempt to reduce the importance of floor area. Multiple values may be a good surrogate for building size, such as number of desks, number of enclosed offices, number of classrooms, length of grocery shelves, etc. These may help spread out the need for accuracy to estimate building size. When using multiple linear regression, most statistical programs let you either allow the program to add the variables in order of significance to the model or else an order can be forced. In the case of building size impacts, it might make sense to use multiple variables that all have to do with building size and put them into the model prior to floorspace. This approach would decrease the importance of the floorspace variable.

9.3 Input Requirements

Arch and Cal-Arch require the least amount of inputs and are probably the quickest for entering data. ENERGYguide and ENERGY STAR require a few more inputs but probably not enough more to greatly affect the effort level compared to Arch or Cal-Arch. Gathering building area, utility bills and other parameters needed by these protocols probably require more time than entering the data on their respective web sites. Both BREEAM and LEED are more comprehensive systems that require information about many aspects of the building besides energy related parameters. LEED-EB, which relies on ENERGY STAR, also has other energy related credits that require additional information. LEED-NC and BREEAM Design rely on simulation methods that require extensive detailed descriptions of the buildings to be analyzed.

The perception of the effort needed to use the protocol may affect its use and, in developing a new protocol, adding additional input requirements should be done reluctantly. Examination of the types of input should also be done with an expectation of the quality of information available to the typical user. For all of the protocols that rely on annual actual energy usage, examining utility bills to determine the quantity of energy used can provide a high level of accuracy. Entering monthly usage, like with ENERGY STAR, probably provides the most trustworthy data input method since errors may occasionally occur when adding together 12 numbers as is required for Arch, Cal-Arch and ENERGYguide.

Adjusting for variation in weather from year to year does require additional inputs, such as the dates covered by the utility bills, but provides additional confidence in the results. This confidence is based on people perception of significant differences in weather from year to year even if this variation is smaller than people believe. Adjusting for actual weather experienced may make a small difference and require additional inputs, but the information is always written on the utility bills and so available to the user without additional data gathering. The ENERGY STAR data entry system allows for multiple periods of data to be entered. This provides the capability to see how building performance changes over time, perhaps before and after an upgrade to the building. This is a good feature but does add some complexity to the interface.

Overall, for a new rating protocol requiring actual energy use, the monthly values, along with an end date should be inputs. Like Arch, Cal-Arch and ENERGYguide, a very simple entry system would be best with additional capability for tracking energy use over time as an option. This would allow most users that are interested in a one time rating to have the easiest interface possible while advanced users who want to monitor their energy use over time could still do so.

9.4 Output and Transparency

The forms of output or results from the protocols examined vary:

- LEED and BREEAM – Several specific grade levels
- ENERGY STAR – Number between 0 to 100 with a specific threshold
- Arch and Cal-Arch – Graphically display the building on a histogram of similar buildings
- ENERGYguide – Depict the usage on a scale like an energy label for appliances

The ENERGYguide and Arch/Cal-Arch approaches provide a direct view of how the energy in the building compares to other buildings. The Arch/Cal-Arch histogram approach may be difficult to understand for less technical users. For an analyst, it is just the kind of information that is interesting but for the typical building operator it is hard to draw a conclusion. In addition, Arch, Cal-Arch and ENERGYguide do not provide any type of target or threshold so it is difficult to conclude what many potential users want to know, is the building good or not?

For normal use, Arch and Cal-Arch provide the greatest transparency of any of the protocols examined. It is very clear that the rated building's energy use is compared to those of other buildings and there is no transformation of the data. The high level of detailed documentation provided by ENERGY STAR gives an energy analyst an exact understanding of how the rating is performed but it is difficult to comprehend the impact of each step for many non-technical users. The appliance style label of ENERGYguide provides a familiar face to the complex topic of building energy rating. It does not include a threshold value like ENERGY STAR but that could be added for a new protocol.

The grade levels used in LEED and BREEAM provide the user a simple way to understand the overall performance but not the level of resolution needed for those looking to understand which of several buildings to invest new energy savings measures into. It would be unlikely that a multiple building comparison would be performed in either LEED or BREEAM due to the effort and expense those protocols require. Given this, the lack of high resolution in the result is not important and instead obtaining a specific level of performance provided by a grade is an incentive for greater energy performance.

9.5 Part of Certification Process

The value of a benchmarking protocol being part of a certification process should not be underestimated. The recognition that ENERGY STAR, LEED and BREEAM offer the building owner is one of the reasons that those benchmarking protocols are used, and perhaps the primary reason for the majority of users. A rating level that is given by a third party provides legitimacy that simply proclaiming a performance level would not provide. The involvement by a third party by providing a certification also means that the protocol must have certain threshold values that pass. In addition, other requirements can be attached to obtaining certification such as providing adequate lighting, ventilation, and comfort like ENERGY STAR does. Performance protocols that are part of a certification process also benefit from greater name recognition since individual building owners and operators start to tout their buildings and how it passed the specific certification process.

If a new building energy performance rating protocol was being developed, it should be written in such a way that is amenable to a certification process. It should include a specific threshold or thresholds to pass and earn higher “grades”. It should also include minimum requirements for the building such as occupancy comfort, code compliant ventilation and adequate lighting levels.

9.6 Effort and Expense

The impact of a rating protocol is influenced by its effort and expense. BREEAM and LEED are relatively labor-intensive protocols, although both cover many environmental issues beyond energy use. They cost in thousands of dollars and require weeks of effort. ENERGY STAR requires much less effort and expense, often less than $1000, and is focused mainly on energy. BREEAM and LEED are well regarded and have a large number of buildings that have been certified, but as a comparison only 154 buildings have LEED certification compared to the 1400 buildings that have been certified by ENERGY STAR. Several of the protocols allow use without charge, using a web site, including Arch, Cal-Arch, ENERGYguide and ENERGY STAR. For ENERGY STAR, approximately 19,000 buildings have been assessed, almost 14 times as many as those obtaining the ENERGY STAR label. Nexus Energy Software reports that 100,000 facilities have been rated using the ENERGYguide method. Arch and Cal-Arch have not had this level of usage but have not been as well publicized or promoted as some of the other protocols.

Given this information, any building energy rating protocol being developed today would be most successful if it allowed people to assess buildings at no charge and required a nominal charge only if the building sought a specific rating as part of a certification process.

9.7 Influences Design or Retrofit

By their very nature, consumption-based protocols such as ENERGY STAR, ENERGYguide, Arch and Cal-Arch, do not integrate well into new building design since they require a year of actual energy consumption. For existing buildings, consumption-based protocols provide direct feedback on energy consumption but do not provide guidance on how to improve the building to obtain a specific rating. This is probably the most significant shortcoming of the consumption-based protocols. Once poor performance is found for a building, the energy professional or designer must try to obtain additional knowledge about the causes of the poor performance in order to identify effective changes and achieve a specific higher score. This means that even if an owner is willing to invest money to alter their building to become an ENERGY STAR labeled building, there are no guarantees of actually achieving that goal.

Design-oriented protocols, such as LEED-NC and BREEAM for design, often use points to reward the inclusion of specific design features. For energy performance, these protocols reward points based on a method such as building energy simulation. Simulation is a good way to compare options but often fails to provide a good prediction of actual energy consumption. This means that design-oriented systems that estimate energy use at design time may result in buildings that use significantly different amounts of energy. Factors such as construction changes, poor commissioning, actual operating schedules, and poor modeling assumptions, can increase actual energy use well beyond the original estimate. On the other hand, if the achievement of a rating is the overall goal, these protocols provide a specific methodology to achieve that goal with minimal risk since actual energy does not impact the rating. Design-oriented protocols cannot apply to existing buildings unless focused on major additions to a building.

Neither design-oriented nor consumption-based protocols provide a guarantee of actually achieving a specific energy performance. Thus, the final link to truly improved energy performance is still missing for all these methods.

Connecting the building designer with the energy impacts of a design is a missing link in the current way buildings are built and operated. The designer rarely knows if a high-performance feature included in the design really has the impact that they expected. Simulation models that may help the designer during the design stage are some help but many of the assumptions needed to use them are not known. Providing tools so that feedback from the actual operation of a building is given to the designer so they can improve their craft may be essential in achieving widespread adoption of high performance buildings.

9.8 Application Baseline

None of the building energy benchmarking protocols evaluated can claim to be the "right" answer. Instead, the protocols evaluated must be viewed relative to one another. Table 80 shows the results for the primary buildings evaluated with each of the protocols. For Cal-Arch, the case with no zip code specified was used. For BREEAM, the points shown are the total points for the Energy section. For LEED-EB, the points are the total points for Energy and Atmosphere. The items shown in bold are the highest rating items for the building type within each rating protocol. The three highest are shown in bold for office buildings, the two highest rated buildings are shown in bold for schools, and the single highest rated building for hospitals. More buildings may be shown in bold if tied with another. Similarly, the items shown in italics are the lowest rated items.

Table 80 – Baseline Ratings Compared

Building	*Arch*	*Cal-Arch*	*BREEAM*	*Energy Star*	*ENERGYguide*	*LEED-EB*
H-035	*80%*	*67*	na	85	*51%*	**11**
H-054	85%	*67*	na	85	60%	8
H-070	**86%**	**84**	na	*75*	**68%**	*5*
H-072	**86%**	*67*	na	**88**	*51%*	**11**
L-021	80%	50	na	96	68%	13
O-013	75%	34	**60**	87	55%	**15**
O-016	*39%*	29	24	*64*	57%	*1*
O-018	**100%**	**65**	24	**90**	**86%**	11
O-022	58%	39	54	*69*	55%	*5*
O-023	**83%**	31	*6*	87	53%	10
O-026	70%	*27*	36	77	*47%*	8
O-027	57%	39	12	92	51%	11
O-028	*38%*	*27*	36	83	50%	12
O-044	73%	**69**	**66**	**94**	**85%**	**18**
O-050	*39%*	28	36	*61*	*49%*	*0*
O-055	78%	**79**	**48**	**95**	**89%**	**13**
O-059	**91%**	34	*6*	86	55%	9
O-076	63%	47	24	83	64%	9
O-089	70%	*27*	*6*	79	*49%*	8
O-096	71%	31	42	71	55%	9
S-003	**88%**	50	na	88	**87%**	11
S-037	**73%**	**58**	na	83	84%	11
S-041	67%	*27*	na	*61*	79%	*3*
S-053	64%	48	na	**92**	*78%*	**14**
S-054	62%	53	na	91	81%	**14**
S-067	*38%*	*35*	na	*36*	84%	*2*
S-069	68%	**53**	na	67	**94%**	4
S-071	69%	50	na	**93**	80%	**14**
S-098	*36%*	35	na	79	*70%*	11

For hospitals, three of the four buildings are rated as the best across protocols showing little agreement. Some specific protocols do tend to show some agreement such as Arch, Cal-Arch and ENERGYguide on H-070. ENERGY STAR and LEED-EB agree on H-072. For schools, six of the nine buildings are considered the top two buildings by some protocol. No more than two protocols agree on including any of these six buildings in the top two. For offices, six of the fifteen buildings are considered the top three from each rating protocol, which indicates much better agreement than for the other building types. Two of the office buildings, O-044 and O-055, are selected as one of the top three buildings by Cal-Arch, BREEAM, ENERGY STAR, ENERGYguide and LEED-EB. Another building, O-018, was selected as one of the top three by four protocols, Arch, Cal-Arch, ENERGY STAR and ENERGYguide. Overall, much more consistency for selecting the top buildings occurs for office buildings than any other building type.

The above table also shows the poorest rated building for each building type with each rating protocol. Each of the hospitals was selected as the worst performing hospital by at least one protocol. For schools, four of the nine schools are in the two worst rated for each protocol including S-069 that is rated as one of the best by Cal-Arch and ENERGYguide and one of the worst by LEED-EB. Offices showed less consistency for the worst buildings with seven buildings being chosen as one of the three worst by a rating method.

Another way of looking at the results is to see if the buildings are consistently rated well by all methods. But what is rated “well”? To earn an ENERGY STAR label a value of 75 is needed, yet an ENERGY STAR score of 60 is the prerequisite for LEED-EB and points are earned at an ENERGY STAR score of 63. Arch, Cal-Arch, and ENERGYguide are examining the building within a range of other buildings and so a percentage of more than 50% is presumably better than average. LEED and BREEAM are looking to reward the best buildings so even their minimum threshold is a building that may be much better than average.

Table 81 shows the buildings that meet the thresholds for the three rating methods with a specific minimum pass or certification level. For LEED-EB, 32 of the 85 possible points are needed to earn certification and a threshold of nine of the 23 Energy and Atmosphere is approximately the same proportion. Similarly, in BREEAM Office 2004, 50 of the possible 858 points are needed to "pass" and using the same proportion, just over six of the 108 Energy points are used as a threshold. Using this approach ENERGY STAR and LEED-EB agree for 18 buildings. For offices, seven of the 15 meet the minimum thresholds of all three rating methods again with ENERGY STAR and LEED-EB agreeing for almost all buildings.

Table 81 – Buildings Earning Minimum Certification

Building	*BREEAM*	*Energy Star*	*LEED-EB*
H-035	-	X	X
H-054	-	X	.
H-070	-	X	.
H-072	-	X	X
L-021	-	X	X
O-013	X	X	X
O-016	X	.	.
O-018	X	X	X
O-022	X	.	.
O-023	.	X	X
O-026	X	X	.
O-027	X	X	X
O-028	X	X	X
O-044	X	X	X
O-050	X	.	.
O-055	X	X	X
O-059	.	X	X
O-076	X	X	X
O-089	.	X	.
O-096	X	.	X
S-003	-	X	X
S-037	-	X	X
S-041	-	.	.
S-053	-	X	X
S-054	-	X	X
S-067	-	.	.
S-069	-	.	.
S-071	-	X	X
S-098	-	X	X
COUNT	12	22	19
Threshold	>6	75	9

Figure 72 compares the scores for the four methods that report values on the scale of 0 to 100, i.e., Arch, Cal-Arch, ENERGY STAR and ENERGYguide. The graph, with ENERGY STAR on the x-axis, shows considerable scatter of results. A line from (0, 0) to (100, 100) is added to aid comparisons. Since most points are below the diagonal line, most buildings score higher on the ENERGY STAR scale than the other scales. Cal-Arch seems to result in particularly low ratings compared to the ENERGY STAR rating for the same buildings.

Figure 72 – Arch, Cal-Arch and ENERGYguide Ratings Compared to Energy Star

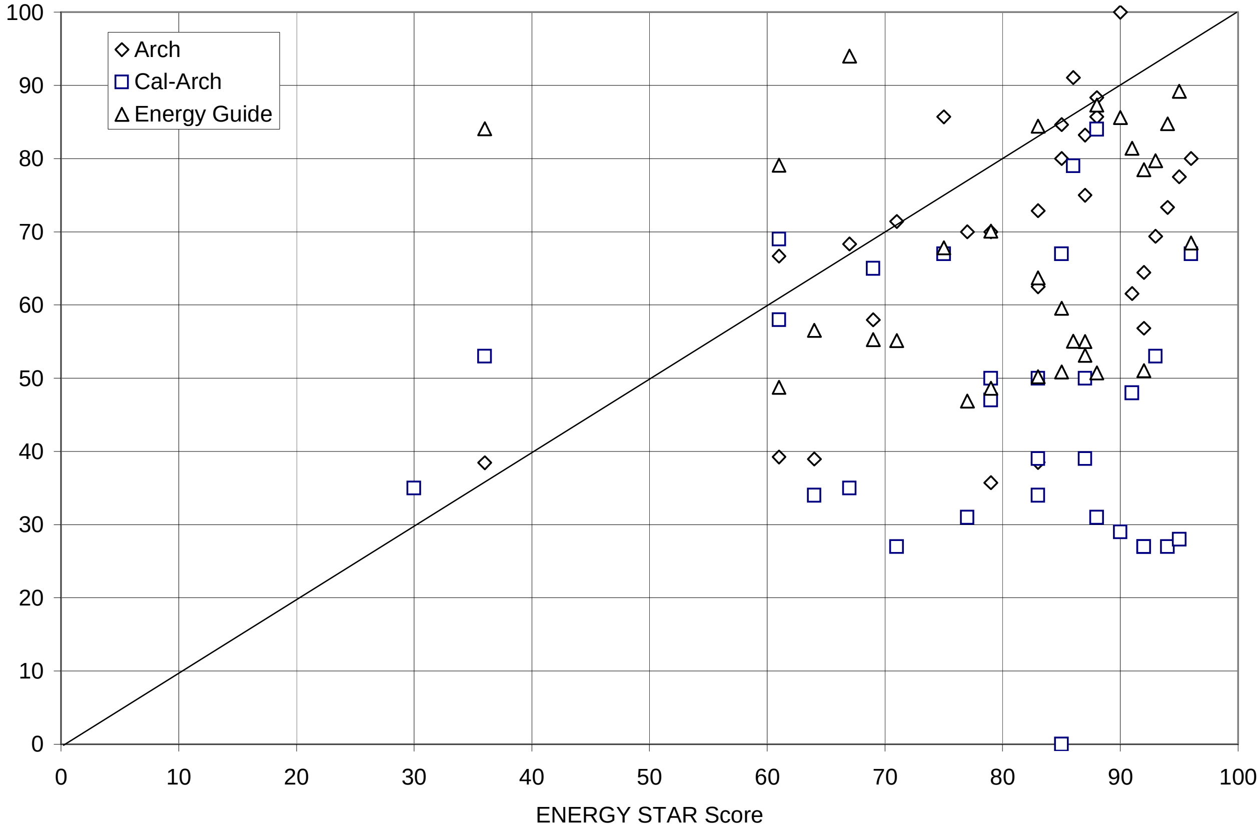


Table 82 is based on adjusting the threshold so that half of the buildings pass each respective rating method. The threshold values are shown at the bottom of the table. Fourteen or fifteen buildings were considered the top half for the rating systems except for BREEAM that only covers offices had eight buildings. Arch, Cal-Arch, ENERGY STAR, and ENERGYguide are all on a scale of 0 to 100. Cal-Arch requires the lowest rating threshold of 48% compared to 85 of ENERGY STAR. Only four of the 29 buildings were not rated in the top half by some rating method and only four buildings were rated in the top half by all the rating methods. Twelve of the buildings were rated in the top half of either all of the rating methods or all but one of the rating methods. Eight of the building where rated in the top half of none or just one rating method. The overall conclusion is that while some exceptionally good buildings are consistently rated well across different rating methods, most buildings could be considered "good" by some rating methods and not others.

Table 82 – Buildings in Top Half

Building	*Arch*	*Cal-Arch*	*BREEAM*	*Energy Star*	*ENERGYguide*	*LEED-EB*	*Count*
H-035	X	X	-	X	.	X	4
H-054	X	X	-	X	.	.	3
H-070	X	X	-	.	X	.	4
H-072	X	X	-	X	.	X	4
L-021	X	X		X	X	X	5
O-013	X	.	X	X	.	X	4
O-016	.	.	.	.	.	.	0
O-018	X	X	.	X	X	X	5
O-022	.	.	X	.	.	.	1
O-023	X	.	.	X	.	.	2
O-026	.	.	X	.	.	.	1
O-027	.	.	.	X	.	X	2
O-028	.	.	X	.	.	X	2
O-044	X	X	X	X	X	X	6
O-050	.	.	X	.	.	.	1
O-055	X	X	X	X	X	X	6
O-059	X	.	.	X	.	.	2
O-076	.	.	.	.	.	.	0
O-089	.	.	.	.	.	.	0
O-096	X	.	X	.	.	.	2
S-003	X	X	-	X	X	X	5
S-037	X	X	-	.	X	X	4
S-041	.	.	-	.	X	.	1
S-053	.	X	-	X	X	X	4
S-054	.	X	-	X	X	X	4
S-067	.	.	-	.	X	.	0
S-069	.	X	-	.	X	.	2
S-071	.	X	-	X	X	X	4
S-098	.	.	-	.	X	X	2
COUNT	14	14	8	15	14	15	
Threshold	71%	48%	25	85	64%	11	

9.9 Input Sensitivity

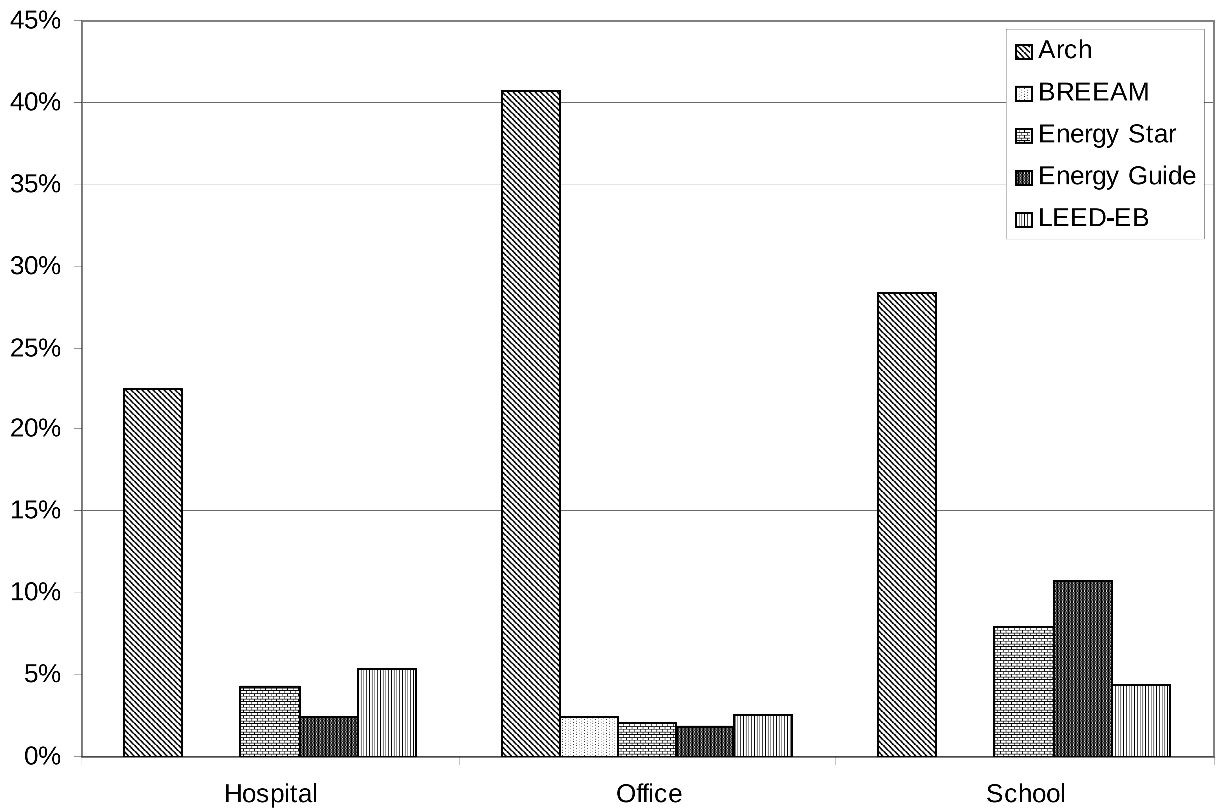
Table 83 shows the input sensitivity cases that were used in more than one of the rating methods. The table does not include additional items from Energy Star that appear in LEED-EB since LEED-EB is based in part on ENERGY STAR with the results mapped to specific point levels. The section on LEED-EB describes this issue in more detail.

Table 83 – Input Cases Common to Multiple Rating Methods

Parameter	*Arch*	*Cal-Arch*	*BREEAM*	*Energy Star*	*ENERGYguide*	*LEED-EB*
COLDZIP	X		X	X	X	X
HOTZIP	X		X	X	X	X
M15ENERGY	X	X	X	X	X	X
P15ENERGY	X	X	X	X	X	X
M15AREA	X	X	X	X	X	X
SITE	X	X				
M15HRS				X	X	X

One way to look at the sensitivity to changing climate without including the impact of where the building is originally located is shown in Figure 73. The figure shows the average difference in the rating between rating the building in Portland, Maine and Dallas, Texas divided by the maximum possible value in the rating or the energy portion of the rating. This shows the average impact by building type for each of the rating methods. The sensitivity by Arch is the largest. ENERGY STAR, ENERGYguide, and LEED-EB are very similar on average with the most sensitivity for schools and least for office. Lodging is not shown since it is only a single building. The large impact under Arch may be due to the limited number of buildings in more extreme climates that are being compared with. The impact of the climate shift shown for offices by the non-Arch rating systems seems too small. The graphs are shown using the average of the absolute values of the difference in the ratings. For most rating methods this has little effect but for ENERGYguide many of the ratings are higher in the cold climate instead of higher in the hot climate especially for schools. The fact that it is close to the other rating methods may be a coincidence.

Figure 73 – Average Climate Shift Impact



The same process was repeated looking at the difference between the two input sensitivity cases that increase and decrease energy consumption by 15%. The total difference of 30% is averaged by building type and shown in Figure 74. The LEED-EB and BREEAM values are for the Energy and Atmosphere and Energy portions of those rating methods, respectively. In all cases, the reduction of energy use resulted in an increase in rating. The different rating methods are remarkably similar on average with a 16 to 23% impact for hospitals, 15 to 20% impact for offices when excluding BREEAM, and 12 to 27% for schools. The very low value for BREEAM is due to a number of reasons. First, the energy section of BREEAM has 150 points and only 60 are related to the CO2 emissions that are affected by energy use. Also, under BREEAM the change due to the 30% energy reduction resulted in 0, 6 or 12 point changes, with eight of the fifteen offices having a 0 point change because of the stair step nature of the rating method. Schools show the greatest spread of ratings due to the change in energy consumption.

Figure 74 – Average Impact of 30% Energy Reduction on Ratings

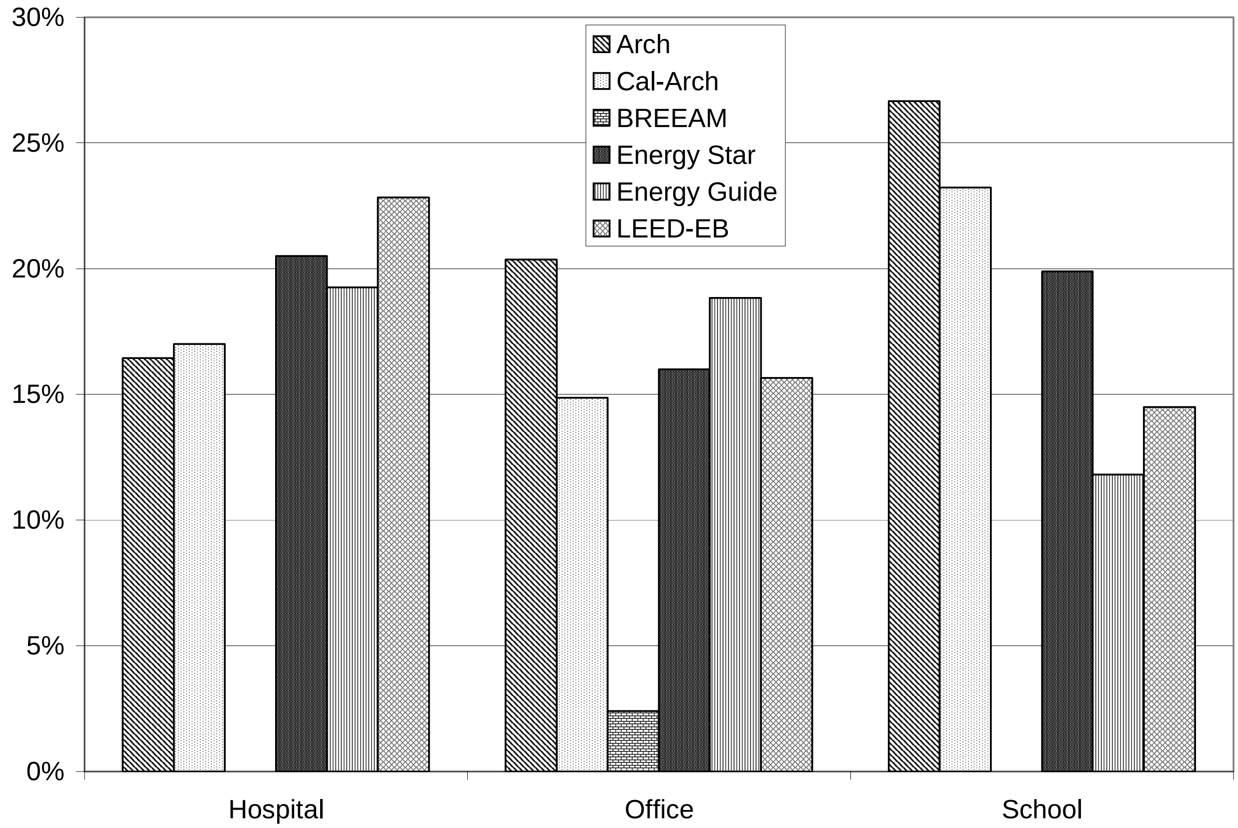
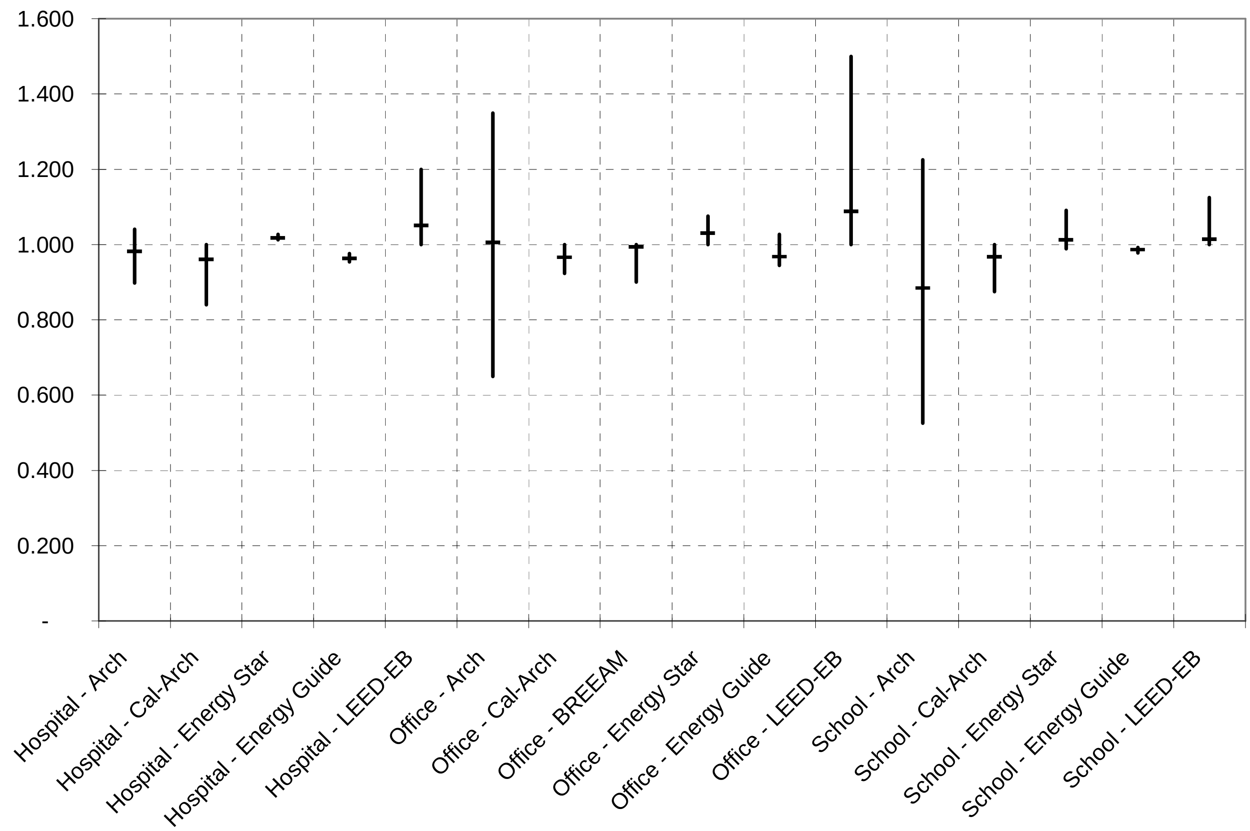


Figure 75 shows the average, maximum and minimum of the ratio of two of the input sensitivity cases. The case examining reducing the area by 15% and the case increasing the energy consumption by 15% should result in nearly the same energy intensity. On the graph, the horizontal line represents the average ratio while the top and bottom of the line represent the minimum and maximum ratios. Energy intensity is not the only factor in these ratings. For Arch and Cal-Arch, the change in area changes the selection of buildings being compared to and this results in some of the largest ranges for those rating methods, especially for Arch in office and school.

Figure 75 – Range of Ratio of Reducing Area 15% to Increasing Energy 15%



Two of the rating methods, Arch and Cal-Arch, have an option for using a site energy basis or a source energy basis. The baseline case was to evaluate on a source energy basis but when the site energy evaluation was used, instead the results did change. Figure 76 shows the ratio of the site energy based rating over the source energy based rating. Given that the methodology of Arch and Cal-Arch is very similar, it is no surprise that they have nearly the same ratios for hospital and office. The ratio for Arch in schools is higher than expected and may be due to a very different selection of buildings when the site evaluation is selected instead of source.

Figure 76 – Average Ratio of Site to Source Ratings

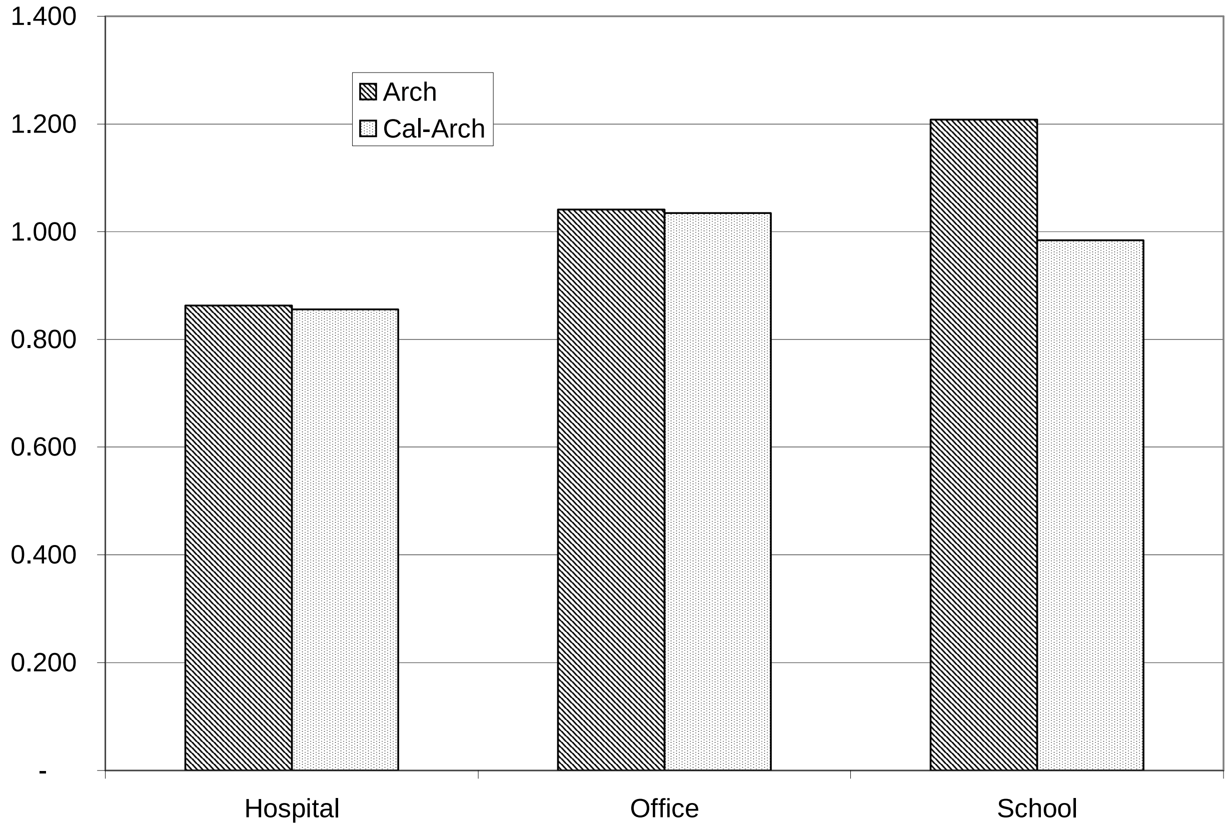
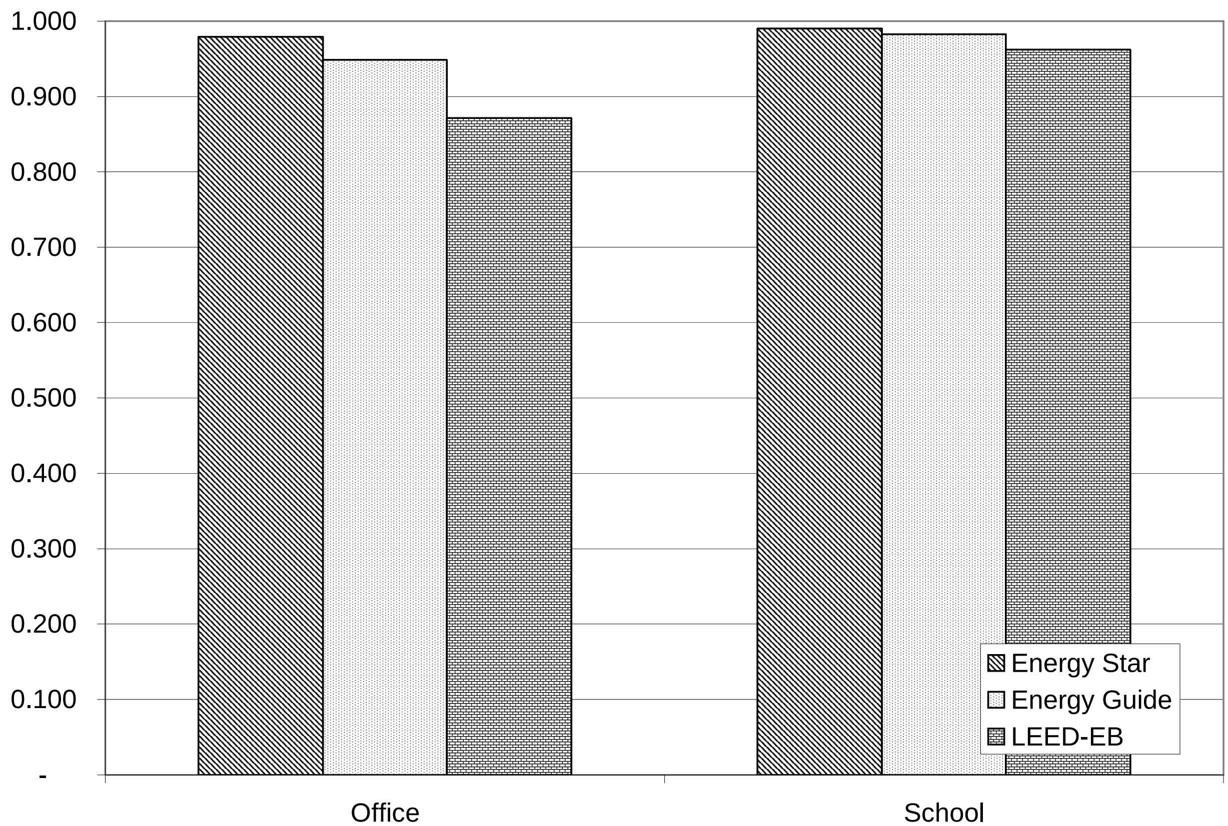


Figure 77 shows the average ratio of the rating with a reduced number of operating hours with the baseline rating for each building. The hours were reduced 15%. This only impacted ENERGY STAR, ENERGYguide and LEED-EB since they had an input for number of operating hours or a schedule of operation. In all cases, the reduction in hours reduced the rating a slight amount with ENERGYguide having a slightly larger impact than ENERGY STAR. The LEED-EB impact is due a few of the cases changing by a full point and others not changing at all.

Figure 77 – Average Ratio of 15% Reduced Hours and Baseline Ratings



9.10 Supplementary Buildings

The supplementary database of buildings provides an opportunity to see broader trends in the data. Figure 78 shows the school buildings from the supplemental database that were valid in ENERGY STAR, ENERGYguide and Arch. While each rating method exhibits some scatter on this figure, the similarity of the overall pattern shows that the three rating methods are similar. The linear trend lines in the graph show that Energy Star increases in rating the fastest with decreasing energy intensity with ENERGYguide next and Arch the slowest at increasing in rating.

Figure 78 – Supplementary Schools Compared

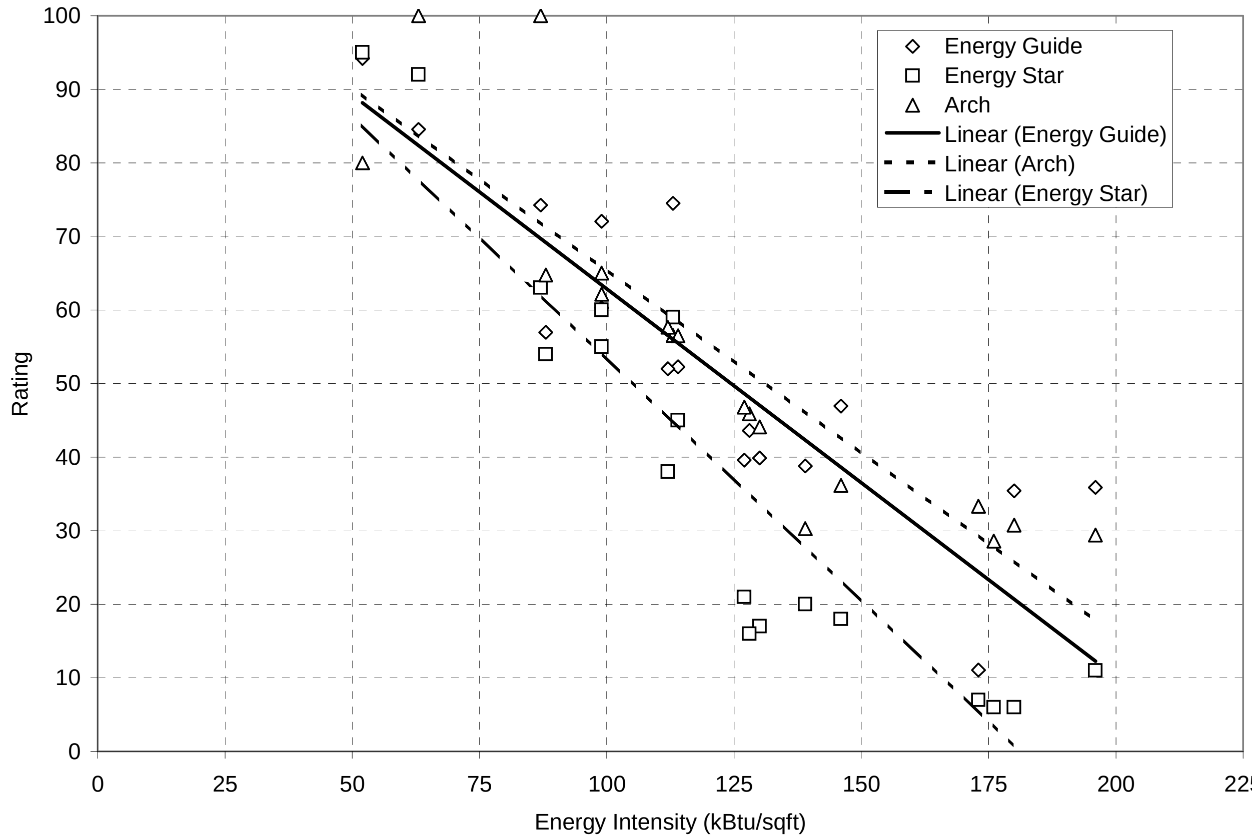
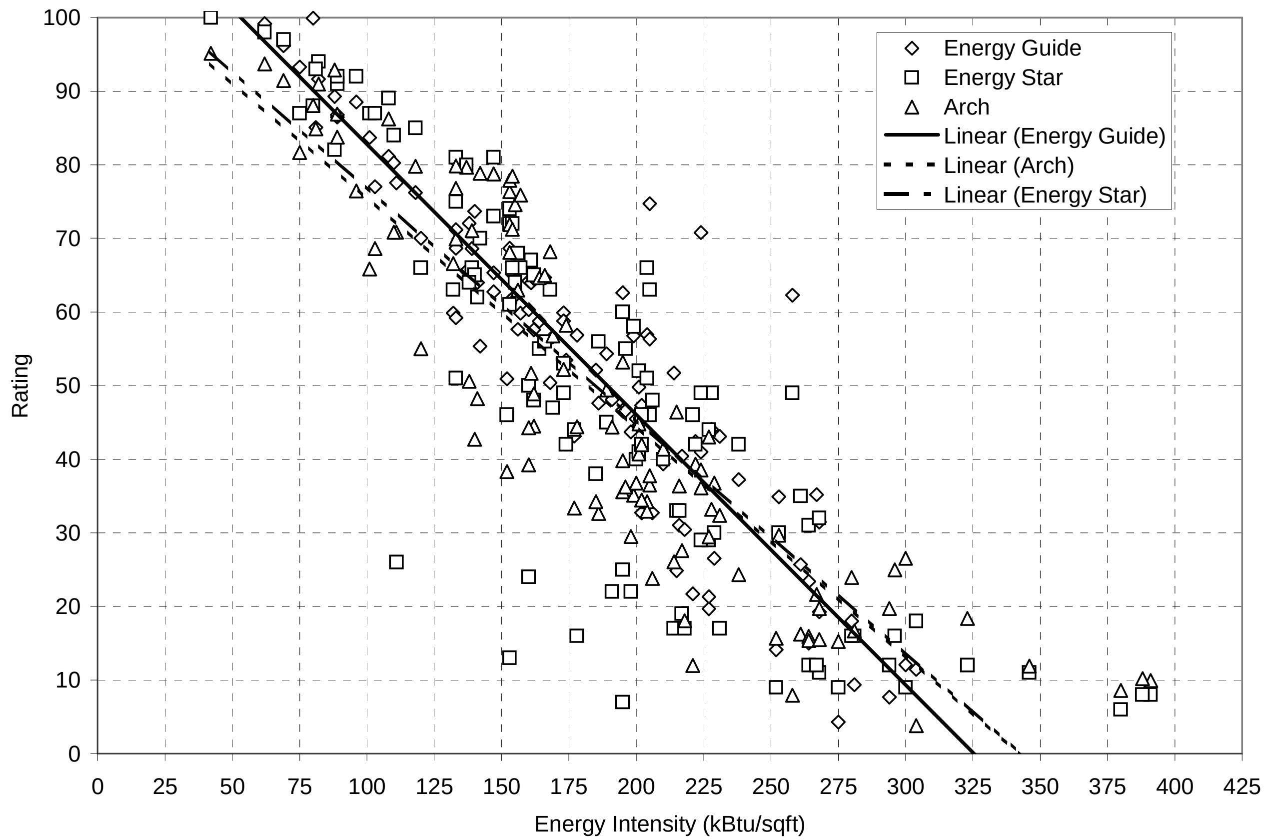


Figure 79 compares the supplemental office buildings that were evaluated with all three rating methods. For offices, the Arch and ENERGY STAR trend lines are very similar with ENERGYguide increasing in rating slightly faster with decreasing energy intensity.

Figure 79 – Supplementary Offices Compared



9.11 Conclusions

The five protocols examined each have their own strengths and weaknesses. Depending on the goals of new protocols, different approaches may be adopted. A deep examination of the protocols has revealed no single clear winner as the best approach overall. The consumption-based protocols such as ENERGYguide, ENERGY STAR, Arch and Cal-Arch, are available for use at no charge and attract many people based on that. Adding a certification process seems to add credibility and spread recognition of the protocol. The consumption based protocols fail in providing good design guidance and feedback during the design process. The point based protocols more directly affect design but require too much effort and expenditure for smaller commercial buildings that make up a very large fraction of the building stock.

10 Recommendations

The first direction stated in the ASHRAE Strategic Plan (ASHRAE 2006) is: “ASHRAE will lead the advancement of sustainable building design and operations.” As part of this direction, one specific strategy included is to “develop performance metrics and rating systems to certify operational performance of buildings for energy efficiency and IEQ.” The following section makes recommendations on how ASHRAE products and services can be improved to better support the five rating protocols studied. The ASHRAE products and services include:

- Standards and guidelines
- Future research
- Training and communications.

In addition, the future research recommendations related to the results of this project were prioritized. The section covers both building performance rating protocols for existing buildings and for the design of new buildings. The application of rating methods in the previous sections was focused only on methods that applied to existing buildings since that was the basis of most of the protocols studied. This section touches on both types of protocols with the recommendations for the protocols intended for new building design based on the analysis performed.

However, before recommendations are made in each area, what ASHRAE currently does and what the society has done in the past is briefly described. For more detailed information about current use of ASHRAE products by the five rating protocols, Section 2 of this report should also be reviewed.

One part of the approach taken was to perform specific searches for the protocols on the ASHRAE web site. Searches were performed in June 2006 using the main search function from the ASHRAE home page, the ASHRAE bookstore search and the ASHRAE abstract search from 1980 to 1997. Abstracts after 1997 were searched as part of the bookstore search. The results of the search are shown in Table 84. LEED has the largest number of references, many due to its close relationship with Standard 90.1, an ASHRAE high profile standard. Many of the main search results are news articles such as press releases including the two Arch results, the two BREEAM results, and many of the LEED results. The scarcity of references for Arch, Cal-Arch, and ENERGYguide was not surprising given that they do not reference any ASHRAE documents, and Arch and Cal-Arch are not actively marketed. BREEAM is used mainly outside the U.S. and the one bookstore reference is to an article about the Canadian version of BREEAM. The lack of ENERGY STAR related search results indicates an unfortunate lack of interest and focus by ASHRAE on a rating protocol that makes good use of ASHRAE documents.

Table 84 – ASHRAE Search Results for Protocols

Protocol	Main Search	Bookstore	Abstracts 80-97
ENERGY STAR	0	1	0
LEED	94	17	0
Cal-Arch/Arch	0	0	0
Arch	2	0	0
BREEAM	2	1	0
ENERGYguide*	0	0	0

*The search term ENERGYguide was also used.

10.1 Standards and Guidelines

By producing standards and guidelines, ASHRAE already provides support to those seeking ENERGY STAR, LEED-EB, and LEED-NC ratings for their buildings since they all reference ASHRAE documents. Arch, Cal-Arch, BREEAM, and ENERGYguide do not include any references to ASHRAE documents including standards or guidelines.

When receiving an ENERGY STAR label, the professional engineer hired to certify the rating utilizes the "Professional Engineer's Guide to the ENERGY STAR Label for Buildings" (EPA 2003) which references the following ASHRAE standards:

- Standard 55-1992 - Thermal Environmental Conditions for Human Occupancy
- Standard 62-1999 - Ventilation for Acceptable Indoor Air Quality
- Standard 52.1-1992 - Gravimetric and Dust Spot Procedures for Testing Air Cleaning Devices used in General Ventilation for Removing Particulate Matte

While Standard 52.1 has not been updated since the reference, Standard 55 was last updated in 2004 and Standard 62 was split into commercial and residential documents in 2003 and both have been updated since then:

- Standard 62.1-2004 – Ventilation for Acceptable Indoor Air Quality
- Standard 62.2-2004 – Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

Since all these standards have been updated, updating the references to them should be considered.

> Recommendation 1 for EPA – Update the references in "Professional Engineer's Guide to the ENERGY STAR ® Label for Buildings" (EPA 2003) to the latest version of Standards 55, 62.1, and 62.2.

Of these, Standards 55, 62.1 and 62.2 are under continuous maintenance and have standing committees at ASHRAE and Standard 52.1 currently has a committee under periodic maintenance procedures. Creating a linkage between those maintaining and developing ENERGY STAR and ASHRAE leads to the following recommendation:

> Recommendation 2 for ASHRAE – Appoint a high level liaison between ASHRAE and EPA to see how Standards 52.1, 55, 62.1, and 62.2 could be improved to enhance their usefulness to ENERGY STAR and find out if any other ASHRAE documents could be used or adapted to used within the ENERGY STAR program.

After the relationship is established, specific liaisons to each standard project committee may be desired. In lieu of a formal liaison relationship with each standard project committee, the committee chair may wish to contact EPA on an annual basis to check if the use of the standard is fulfilling the needs within the ENERGY STAR program.

To guide this relationship the following is recommended to EPA and ASHRAE:

> Recommendation 3 for ASHRAE and EPA – Agree to a Memorandum of Understanding between ASHRAE and EPA establishing and maintaining a mutually beneficial relationship related to ENERGY STAR and ASHRAE standards, research, training, and communications.

Both LEED-NC 2.2 (USGBC 2005) for new construction and LEED-EB 2 (USGBC 2005) for existing buildings directly reference a large number of ASHRAE documents as shown in Table 85.

Table 85 – References to ASHRAE Documents

Document	LEED-NC	LEED-EB
ASHRAE 52.2-1999 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size	x	x
ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy	x	x
Standard 62.1-2004 Ventilation for Acceptable Indoor Air Quality	x	x
Standard 62 Users Manual	x	
Standard 90.1-2004 Energy Standard for Buildings Except Low-Rise Residential Buildings	x	
Standard 90.1-2004 Users Manual	x	
Advanced Energy Design Guide for Small Office Buildings	x	

A previous version of LEED-NC, version 2.1, had an additional reference to Standard 129-1997, Measuring Air Change Effectiveness.

ASHRAE is working with USGBC, the organization behind LEED, to develop Standard 189 and the advanced energy design guides. The ASHRAE standards referenced by USGBC are the latest published versions available. ASHRAE has standing project committees for 52.2, 55, 62.1 and 90.1. The recommendations related to the LEED program follow.

> Recommendation 4 for ASHRAE – Appoint a liaison between ASHRAE and USGBC to help enhance 52.2, 55, 62.1, and 90.1 to better meet the needs of USGBC for their LEED-NC for new construction and LEED-EB for existing buildings.

The liaison appointed should communicate with members of both organizations annually concerning plans and problems to identify where the other organization may be able to assist. In addition, the liaison should report at regular meetings of each organization on the relevant news from the other organization. The ideal liaison is one who is familiar with both organizations and with all related documents and who regularly attends meetings hosted by both organizations.

This process has worked in the past. During the development of Appendix G to Standard 90.1-2004, members of USGBC frequently attended Energy Cost Budget subcommittee meetings. One addendum to Appendix G was aimed at addressing specific concerns on how it would be used with LEED-NC. The latest version of LEED-NC changed its reference from Section 11 of 90.1 to Appendix G since USGBC felt the appendix better suited its needs.

The following recommendation is not directly tied to one of the studied protocols but instead is a recommendation on a specific ASHRAE standard. Standard 90.1 covers the energy related design of new buildings but building designers do not receive feedback on how the actual building performed after construction is complete and operation begins. Architects and engineers end up without feed back on their design decisions. To overcome this, the following recommendation is made:

> Recommendation 5 for ASHRAE – In Standard 90.1, create a method of rating energy performance from design to operation which uses the same scale and report operation results back to the original design team.

10.2 Prioritized Future Research

The following paragraphs describe research that ASHRAE may wish to perform. The research topics are in order of highest priority to lowest. These research projects do not all support a specific rating method but would provide the resources for possible future enhancements to many different rating methods.

1. *Characterize Buildings Missing From ENERGY STAR*
   Certain building types, such as retail, are not represented in ENERGY STAR. These building types should be better characterized so they can be used in rating systems. One issue is the large number of building subtypes that may have very different levels of energy consumption due to their lighting levels or other building requirements. The research project would identify the major categories of buildings missing from the ENERGY STAR tool and characterize the energy factors for those buildings.

2. *Reconnect Energy Design Codes and Actual Energy Consumption*
   Building energy consumption varies by climate, building type, operation, and specific design parameters. Many of the design parameters are based on building energy codes or standards. The impact of these sets of parameters from energy codes and standards on actual energy use has never been studied. An examination of buildings built under various energy codes and their historical energy consumption would help inform those developing new energy codes. In addition, it would also help establish the baseline values for building energy benchmarking. There is a disconnect between design of a building and its energy consumption. In an ideal world, programs using rating methods would be able to only reward buildings that exceed the design of a minimally compliant building. Establishing a connection between building energy code compliant design and operational energy consumption would provide a baseline for incentive programs. This project would follow performance of specific buildings over time from design to operation. It would examine the building performance over the first few years of operation while typical start-up issues are being resolved.

3. *Develop Requirements for Building Energy Rating Protocols*
   The wide range of rating protocol methods can provide a variety of perspectives on what separates a good and bad energy performing building. This diversity also creates chaos in the eyes of those that are trying to use these rating methods. The ability for a building operator to "shop" different rating protocols until they find one that supports their position diminishes the value of all building energy rating protocols. ASHRAE should consider developing a standard set of requirements for rating protocols and allow vendors of specific methods to state that they comply with the ASHRAE standard. The first step to developing such a standard of requirements would be a research project based on the results of this project. See the later section titled "New Rating Protocol Recommendations" for more detailed recommendations.

4. *Develop Building Energy Intensity Distributions*
   Analysis of building energy consumption intensity distributions by building type and major characteristics would provide information to be used by others developing benchmarks. The energy intensity data could also be used by engineers, building owners, and building operators as benchmarks to understand their own buildings. Utilize engineering or statistical methods to extend the distributions to different climates covering very specific building types. Use data from multiple databases such as CBECS, RECS, NWEEA, CEUS, BOMA, HUD, Census, Dodge, and GSA to provide additional detail. Often knowledge of how a building performs compared to a peer group is sufficient to motivate stakeholders for underperforming buildings to invest in energy efficiency improvements. Results of this type of research would ideally be widely disseminated.

5. *Improving Benefits from Building Energy Surveys*
   A survey of energy consumption and energy characteristics of buildings is a large undertaking. ASHRAE may choose to perform such a survey or to provide information to others performing such surveys that would help them gather data relevant to ASHRAE. The research could examine current surveys such as CBECS, RECS, NWEEA, CEUS, BOMA, HUD, Census, Dodge, GSA and their

survey instruments and determine which inputs would be most useful to establishing data for rating methods and other ASHRAE programs. From this a set of survey questions that would be desirable could be developed. The survey could then be performed or the research results could be provided to those that normally perform such surveys. One particular issue that should be assessed is whether sensitivity to the gathering of energy consumption data is based on customer requests for confidentiality or on utility concerns over revealing their customers' energy profiles to competitors. During the research project, almost all of those asked were willing to provide utility data. Constraints on releasing energy data is a major obstacle in any building energy survey, and being aware of the issues allows researchers to better plan their projects.

6. *Focused Building Energy Surveys*
   Targeted surveys are well within ASHRAE capabilities such as one focused on schools with a limited number of questions concerning benchmarking parameters. This may be the first step in ASHRAE establishing recommendations or a protocol for evaluating school energy use.
7. *Develop Submeter Energy Benchmarks*
   Examine actual buildings that are submetered and develop benchmarks for submetered components and submetered groups of components. The study must be broad enough across building types to understand the subtleties of the variation in operating hours and operating characteristics of different components. This would build on the work of RP-1093 Compilation of Diversity Factors and Schedules for Energy and Cooling Load Calculations but expand the scope and try to utilize data from other sources. This would lead to better building load profiles.
8. *Building Categorization Based on Major Energy Parameters*
   Different systems are used to divide the population of commercial buildings into groups, often called building types. These systems are based on surveys and building codes but may not be the best way to categorize building in regards to energy consumption characteristics. A research project aimed specifically at defining building types or a hierarchy of building types and subtypes could help in many areas at ASHRAE. Energy conservation measures and impacts of major parameters depend on the type of building and if the categorization was better defined, the help could be better targeted. Within each building type, the impact of different parameters could be examined. The energy impact of the presence of an indoor swimming pool is different for a high school and for hotel. The differences may be pronounced even within these categories. A study looking at building type categorization and major energy parameters within each building type would help ASHRAE target future research.

The following recommendation is directed at high-level ASHRAE committees controlling the overall research program and it's funding.

> Recommendation 6 for ASHRAE – Increase the level of funding and maintain a high level of funding to provide research in support of energy performance rating protocols.

10.3 Training and Communication

ASHRAE currently provides a broad range of information to its members via its magazine *ASHRAE Journal*, papers and presentations, on-line training, and in-person training. ASHRAE provides training on a variety of topics of interest and importance to their membership. Training ranges from on-line courses to multiple day courses teaching both fundamentals needed for new engineers such as load calculations, to advanced topics for seasoned professionals. Given the diversity of interests of ASHRAE members, it is appropriate that only a small fraction of articles and papers are related to building energy performance rating protocols. Many of the articles that do exist are related to LEED-NC, perhaps due to its close reliance on ASHRAE Standard 90.1. The U.S. Green Building Council holds training sessions for complying with LEED-NC and LEED-

EB and becoming LEED-NC and LEED-EB accredited professionals. ASHRAE could target training to engineers provide services related to LEED-EB or LEED-NC. One specific area of training would be how to use Standard 90.1 appendix G to show compliance with LEED-NC. Since no training is available from ASHRAE specifically on LEED-NC, the following is recommended:

> Recommendation 7 for ASHRAE - Provide ASHRAE training for LEED-NC and LEED-EB compliance, focusing on applying the referenced ASHRAE standards.

The rating protocols evaluated in this report other than LEED are largely absent from the ASHRAE literature, see Table 37 in the previous section for details. This is an unfortunate omission, especially for ENERGY STAR. The reliance on ASHRAE Standard 55, 62, and 52.1 in order to obtain an ENERGY STAR Label for Buildings means that ASHRAE could play a critical role in providing an understanding of how those standards can be applied during the certification process for ENERGY STAR Label for Buildings. The ENERGY STAR Building Label rating method requires a professional engineer to certify that the energy consumption and the building area used in the rating along with other inputs was performed accurately. In addition, air quality and lighting levels need to be code compliant. While EPA provides some materials for educating engineers to perform these functions, additional training targeted to mechanical engineers who may or may not be members of ASHRAE would be useful. While training exists on EPA's web site, ASHRAE has the best depth of knowledge on these standards and should consider the following:

> Recommendation 8 for ASHRAE – An article concerning ENERGY STAR and the ASHRAE standards it references should appear in a future ASHRAE Journal.

> Recommendation 9 for ASHRAE – Develop and provide a training course on ENERGY STAR and the ASHRAE standards it references.

Concerning BREEAM, Arch, Cal-Arch and ENERGYguide, it would certainly be within ASHRAE's scope to provide technical articles or training on these protocols, but since they lack direct ties to ASHRAE, ASHRAE would not have any unique perspective to offer.

Another possible type of training would be aimed at mechanical engineers hired to help upgrade a building to qualify under a rating program such as LEED or ENERGY STAR. Understanding how to design and implement energy conservation measures in order to allow a building to qualify may require additional training.

> ASHRAE Recommendation 10 – Develop and provide a training course about energy conservation measures for new and existing buildings and how engineers can assess the energy impact of changes.

10.4 New Rating Protocol Recommendations

The deep understanding gained by the study and analysis of the different rating methods serves as a basis for making the following recommendations on what features and methodologies could be included in a future building energy performance rating protocol. A rating method protocol could be a standard, a guideline or a service that ASHRAE provides.

- The protocol should focus on the energy performance of buildings.
- Ease-of-use is high priority since non-technical building owners and operators are part of the target user audience.

- Adopt a clear goal during the development of the rating method such as to recognize and encourage high performance buildings and discourage low performance buildings.
- Develop methodology using empirical data from building energy surveys such as CBECS, RECS, NWEEA, CEUS, BOMA, HUD, Census, Dodge, GSA. This improves confidence by both experts and users in the rating method.
- Assuming a protocol is used for many years, the protocol should be easily updated to the newest building data as it becomes available.
- The rating should be by major building type or by subtypes for certain buildings.
- The rating method should utilize a multiple regression model with additional smoothing (similar to ENERGY STAR).
- Location/climate dependency may need to be modeled using building energy simulation programs since that is often masked by the building energy survey databases which do not report actual location for confidentiality reasons.
- Publicly document the rating method so that experts in the field can gain an understanding of the methodology and provide assurances to users.
- Allow for ratings via a web site with very few inputs required. The inputs should include monthly utility energy consumption for electricity and major fuels, building type, building area, and ZIP code. Additional inputs should be carefully evaluated and only included if it is very easy for the user to answer and later to verify if certification is included. Inputs will vary by building type but should be as uniform as possible.
- Use a scale from 0 to 100 corresponding to the percent of buildings that use more energy but extend the scale to 125 for buildings that are net-zero energy consuming buildings. This scale is similar to academic test results and would be easily understood by most people. The maximum of 125 is a method to extend the scale and other maximum values may be just as valid.
- Provide a very simple graphical output similar to an appliance energy label that shows the building and the full scale with predefined thresholds indicated.
- A histogram graph of the number of buildings and different energy consumption levels would be available but not the primary graphical view since it is confusing to many users. Such a histogram would show a large number of buildings by representing them through the regression model.
- Allow free use of the rating protocol via a web site but charge for a certification. This would encourage wide spread use.
- Integrate the empirical rating method with the design process by using energy estimates and compare them to precalculated scores for buildings that achieved Standard 90.1, IECC, Advanced Energy Design Guide, and other predetermined thresholds. This shall be based on building simulation and shall be considered tentative until the building has been operated for three years.
- Limit the rating method to building energy performance instead of an entire environmental rating method since it is easier to understand, easier to verify, and one of the most important aspects.
- Combine energy use in the rating algorithm using CO2 factors recognizing global warming as one of the most important reasons for encouraging higher performance buildings.
- Include weather normalization to provide nearly the same score for a building from year-to-year.
- Include in the web site specific recommendations by building type on how to improve the score of a building starting with a simple self-audit methodology and including examples on how a variety of energy conservation measures have helped actual buildings improve.

- The web site input and output should be optimized for a person rating a single building and should require only one input page and one result page.
- The web site shall allow users to create an account before or after performing a rating and save their data or to download the information without creating an account. This would encourage wide spread use and include the segment of the population uncomfortable with providing personal data on the Internet.
- All major browsers should be supported including Internet Explorer, Opera, Firefox, and Safari and advanced features such as dynamic page elements may be used if supported across all browsers.
- Advanced users that have multiple buildings or are entering data over time can use a more advanced web site similar to ENERGY STAR's Portfolio Manager. Comparison across buildings should be on a single page and show each building and their rating sorted by their rating.
- For very advanced users with a large number of buildings, allow files to be used for input and output via an FTP site.
- Scores from multiple buildings could be combined for an overall campus score for hospitals and universities.
- Create an easy method for a user to enter their utility account information and authorize their utility companies to provide an automatic monthly update of their consumption along with software methods for utilities to provide this data easily. Scores can then be emailed to the user monthly or quarterly.
- Entered utility account information would also allow for direct access to information from programs the utility may provide to perform audits or other programs to increase building energy performance.
- Training for learning how to use the benchmarking system should be available on the web with more in-depth training available during ASHRAE meetings.
- Benchmarking the same building over time should be easy with a graph of how the score has changed over time being generated.
- Allow benchmarking system to be available by utilities and others so they can integrate it with their web sites.
- An optional set of simple environmental criteria could earn an additional "plus" rating to cover the major and easily verified environmental criteria.

From choosing the source of the comparison data, to segmenting that data into categories, to determining what the inputs and outputs are, almost all decisions made in developing a building energy rating system, no matter how technical, end up having policy impacts as well. Which buildings are rated at all, which are rated higher or lower, and what energy conservation features are credited have policy impacts. Instead of trying to ignore these policy issues or attempting to make a completely neutral rating system, the policy issues should be faced during the earliest stages of development. A clear set of policy goals that is amended as new choices are made can help guide the development of a rating system. The setting of policy goals is especially relevant if the rating system is going to be a component in a broader program that provides incentives or rewards to building owners that score well.

Several of the recommendations are specifically on the use of a certification program with the proposed building energy performance rating protocol. Certification provides recognition of achievement that is often necessary to justify building improvements to building owners, developers, and operators. Including certification will increase use of the benchmarking system.

- Public relations benefits from achieving a rating threshold are usually the main goal for most building owners so maximize this impact through public disclosure on ASHRAE web site and listing new projects in ASHAE Journal, Insights, or email newsletter.
- Create a certification program around the rating method that does not require a central review process but instead relies on mechanical engineers with a professional engineering license as “raters” who have trained (on-line or in-person) and passed a certification test (given on-line) and have agreed to abide by a code of ethics to evaluate and approve the rating. This reduces complexity, expense and time in receiving a certification increasing the likelihood of many buildings being certified.
- The certification would include checking by raters for adequate ventilation, lighting, comfort, and occupancy to ensure that the building is meeting the basic needs of the occupants.
- During certification, a specific method of determining building floor area and utility energy consumption should be used.
- Set a threshold level, such as having higher energy performance than 75% of the buildings, for earning an award in the certification program.
- Include additional awards for obtaining even higher ratings, such as 85, 95, 110. These levels can be associated with silver, gold and platinum or a number of stars. These more aggressive levels would require two independent engineers approve the rating and would require the presence of energy efficient measures or operations. A minimum occupant density, percent area occupied, and weekly hours of operation would also be required.
- Include a different award in the certification program for large one-time improvements and for continuous smaller improvements over multiple years even if below normal certification threshold to encourage making poor buildings better. Before and after evaluations would need to be performed by the engineer and specific building energy conservation improvements must be shown.
- Certifications should be dated with an expiration date. An email and written notification should be sent when certification will expire. Buildings previously certified should be listed as “expired” on web site to encourage renewal.

10.5 Summary and Conclusion

The five rating methods that were investigated and tested as part of this project provided a good cross section of different approaches. It is clear that the need for robust and easy-to-use rating methods for buildings will only increase as escalating energy prices brings an increasing awareness to energy conservation. The recommendations discussed in this section are reiterated below:

1. Update the references in “Professional Engineer's Guide to the ENERGY STAR ® Label for Buildings” (EPA 2003) to the latest version of Standards 55, 62.1, and 62.2.
2. Appoint a high level liaison between ASHRAE and EPA to see how Standards 52.1, 55, 62.1, and 62.2 could be improved to enhance their usefulness to ENERGY STAR and find out if any other ASHRAE documents could be used or adapted to used within the ENERGY STAR program.
3. Agree to a Memorandum of Understanding between ASHRAE and EPA establishing and maintaining a mutually beneficial relationship related to ENERGY STAR and ASHRAE standards, research, training, and communications.
4. Appoint a liaison between ASHRAE and USGBC to help enhance 52.2, 55, 62.1, and 90.1 to better meet the needs of USGBC for their LEED-NC for new construction and LEED-EB for existing buildings.

5. In Standard 90.1, create a method of rating energy performance from design to operation which uses the same scale and report operation results back to the original design team.
6. Increase the level of funding and maintain a high level of funding to provide research in support of energy performance rating protocols.
7. Provide ASHRAE training for LEED-NC and LEED-EB compliance focusing on applying the referenced ASHRAE standards.
8. An article concerning ENERGY STAR and the ASHRAE standards it references should appear in a future ASHRAE Journal.
9. Develop and provide a training course on ENERGY STAR and the ASHRAE standards it references.
10. Develop and provide a training course about energy conservation measures for new and existing buildings and how engineers can assess the energy impact of changes.

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Appendix A – Questionnaires

ASHRAE 1286-TRP Research Project Office Questionnaire for LEED-EB Buildings

Instructions

The questionnaire is to gather information about your building so it may be assessed using five different benchmarking systems as part of ASHRAE research project 1286-TRP. The five benchmarking systems are LEED-EB, ENERGY STAR for Buildings, ARCH/CAL-ARCH, EnergyPrism, and BREEAM. Using the dropdown lists makes completing this questionnaire simpler. Please complete this questionnaire and send it by email to Jason Glazer at jglazer@gard.com.

Questions? Ask Jason Glazer 847 698 5686 or jglazer@gard.com
GARD Analytics, 1028 Busse Hwy, Park Ridge, IL 60068, www.gard.com, FAX 847 698 5600

Identification	**Response**
Name	
Building Name	
ZIP Code	
General Building Information	
Building Energy Code	
Year Facility Built	
End-Use Energy Sources	
Primary Heating Source	
Secondary Heating Source	
Primary Cooling Source	
Secondary Cooling Source	
Water Heating Source	
Refrigeration	
Gas Cooking	
Electric Cooking	
Gas Laundry	
Electric Laundry	
Interior Lighting	
Exterior Lighting	
Physical and Operation Building Attributes	
Total Floor Area (sqft)	
Unheated Floor Area Included in Total (sqft)	
Number of Floors	
Percent Air Conditioned	
Weekday opening time	
Weekday closing time	
Saturday opening time	
Saturday closing time	
Sunday opening time	
Sunday closing time	
Closed or limited operation in summer?	
Closed or limited operation in winter?	
Percent Open Office Plan	

Points from Non-LEED Benchmarks

Written and distributed an energy policy?	
Is cooling electric separately metered?	
Is heating energy separately metered?	
Is fan electric separately metered?	
How many companies are in the building?	
Are tenants separately metered?	
Prestige or headquarters building?	
Naturally Ventilated?	
Year of last energy audit.	
Target reduction of energy use.	
Movement toward target reduction of energy use	
Maintain records of lighting fixtures	

Authorizations

I authorize USGBC to share LEED-EB scorecard data for my building with GARD Analytics and ASHRAE.	
I authorize EPA to share data on my building from ENERGY STAR's Portfolio Manager with GARD Analytics and ASHRAE.	
I authorize GARD Analytics and ASHRAE to include the identify of my building in published reports.	

ASHRAE 1286-TRP Research Project Office Questionnaire

Instructions

The questionnaire is to gather information about your building so it may be assessed using five different benchmarking systems as part of ASHRAE research project 1286-TRP. The five benchmarking systems are LEED-EB, ENERGY STAR for Buildings, ARCH/CAL-ARCH, EnergyPrism, and BREEAM. Using the dropdown lists makes completing this questionnaire simpler. Please complete this questionnaire and send it by email to Jason Glazer at jglazer@gard.com.

Questions? Ask Jason Glazer 847 698 5686 or jglazer@gard.com
GARD Analytics, 1028 Busse Hwy, Park Ridge, IL 60068, www.gard.com, FAX 847 698 5600

	Response
Identification	
Name	
Building Name	
ZIP Code	
General Building Information	
Building Energy Code	
Year Facility Built	
End-Use Energy Sources	
Primary Heating Source	
Secondary Heating Source	
Primary Cooling Source	
Secondary Cooling Source	
Water Heating Source	
Refrigeration	
Gas Cooking	
Electric Cooking	
Gas Laundry	
Electric Laundry	
Interior Lighting	
Exterior Lighting	
Physical and Operation Building Attributes	
Total Floor Area (sqft)	
Unheated Floor Area (sqft)	
Number of Floors	
Percent Air Conditioned	
Weekday opening time	
Weekday closing time	
Saturday opening time	
Saturday closing time	
Sunday opening time	
Sunday closing time	
Closed or limited operation in summer?	
Closed or limited operation in winter?	
Percent Open Office Plan	
Points from Specific Benchmarks	
Building operation plan developed and followed?	
Are CFC refrigerants used in the building?	
Percent of use is off-site (Green-e) renewable	
Percent of use is on-site renewable	
24 hours of maintenance staff traning annually	

Preventative maintenance program	
Performance monitoring of space conditioning equipment	
Are HCFC or Halon used in the building?	
Refrigerant loss rate per year	
Is lighting electric separately metered?	
Are plug or process electric separately metered?	
Track, record and report emission reduction efforts?	
Document sustainable building cost impacts?	
Written and distributed an energy policy?	
Is cooling electric separately metered?	
Is heating energy separately metered?	
Is fan electric separately metered?	
How many companies are in the building?	
Are tenants separately metered?	
Prestige or headquarters building?	
Naturally Ventilated?	
Year of last energy audit.	
Target reduction of energy use.	
Movement toward target reduction of energy use	
Maintain records of lighting fixtures	

Authorizations

I authorize EPA to share data on my building from ENERGY STAR's Portfolio Manager with GARD Analytics and ASHRAE.	
I authorize GARD Analytics and ASHRAE to include the identify of my building in published reports.	

ASHRAE 1286-TRP Research Project School Questionnaire

Instructions

The questionnaire is to gather information about your building so it may be assessed using five different benchmarking systems as part of ASHRAE research project 1286-TRP. The five benchmarking systems are LEED-EB, ENERGY STAR for Buildings, ARCH/CAL-ARCH, EnergyPrism, and BREEAM. Using the dropdown lists makes completing this questionnaire simpler. Please complete this questionnaire and send it by email to Jason Glazer at jglazer@gard.com.

Questions? Ask Jason Glazer 847 698 5686 or jglazer@gard.com
GARD Analytics, 1028 Busse Hwy, Park Ridge, IL 60068, www.gard.com, FAX 847 698 5600

Identification	Response
Name	
Building Name	
ZIP Code	
General Building Information	
Building Energy Code	
Year Facility Built	
End-Use Energy Sources	
Primary Heating Source	
Secondary Heating Source	
Primary Cooling Source	
Secondary Cooling Source	
Water Heating Source	
Refrigeration	
Gas Cooking	
Electric Cooking	
Gas Laundry	
Electric Laundry	
Interior Lighting	
Exterior Lighting	
Physical and Operation Building Attributes	
Total Floor Area (sqft)	
Unheated Floor Area (sqft)	
Number of Floors	
Percent Air Conditioned	
Percent Mechnical Ventilation	
Percent Natural Ventilation	
Weekday opening time	
Weekday closing time	
Saturday opening time	
Saturday closing time	
Sunday opening time	
Sunday closing time	
Closed or limited operation in summer?	
Closed or limited operation in winter?	
Points from Specific Benchmarks	
Building operation plan developed and followed?	
Are CFC refrigerants used in the building?	
Percent of use is off-site (Green-e) renewable	
Percent of use is on-site renewable	

24 hours of maintenance staff traning annually	
Preventative maintenance program	
Performance monitoring of space conditioning equipment	
Are HCFC or Halon used in the building?	
Refrigerant loss rate per year	
Is lighting electric separately metered?	
Are plug or process electric separately metered?	
Track, record and report emission reduction efforts?	
Document sustainable building cost impacts?	
Written and distributed an energy policy?	
Is cooling electric separately metered?	
Is heating energy separately metered?	
Is fan electric separately metered?	
How many companies are in the building?	
Are tenants separately metered?	
High mass building with night-time precooling?	
Ground, groundwater, or surface water based cooling?	
Evaporative cooling?	
Desiccant or absorption cooling using waste heat?	
Displacement ventilation?	
Internal and external lights average efficacy of at least 65 lumens/watt?	
Internal and external lights average efficacy of at least 100 lumens/watt?	
Capacity of water heaters	
Type of construction	
Heat distribution system	
Boiler efficiency	
Glazing	

Authorizations

I authorize EPA to share data on my building from ENERGY STAR's Portfolio Manager with GARD Analytics and ASHRAE.	
I authorize GARD Analytics and ASHRAE to include the identify of my building in published reports.	

ASHRAE 1286-TRP Research Project Hospital Survey

Instructions

The questionnaire is to gather information about your building so it may be assessed using five different benchmarking systems as part of ASHRAE research project 1286-TRP. The five benchmarking systems are LEED-EB, ENERGY STAR for Buildings, ARCH/CAL-ARCH, EnergyPrism, and BREEAM. Using the dropdown lists makes completing this questionnaire simpler. Please complete this questionnaire and send it by email to Jason Glazer at jglazer@gard.com.

Questions? Ask Jason Glazer 847 698 5686 or jglazer@gard.com
GARD Analytics, 1028 Busse Hwy, Park Ridge, IL 60068, www.gard.com, FAX 847 698 5600

	Response
Identification	
Name	
Building Name	
ZIP Code	
General Building Information	
Building Energy Code	
Year Facility Built	
End-Use Energy Sources	
Primary Heating Source	
Secondary Heating Source	
Primary Cooling Source	
Secondary Cooling Source	
Water Heating Source	
Refrigeration	
Gas Cooking	
Electric Cooking	
Gas Laundry	
Electric Laundry	
Interior Lighting	
Exterior Lighting	
Physical and Operation Building Attributes	
Total Floor Area (sqft)	
Unheated Floor Area (sqft)	
Number of Floors	
Percent Air Conditioned	
Points from Specific Benchmarks	
Building operation plan developed and followed?	
Are CFC refrigerants used in the building?	
Percent of use is off-site (Green-e) renewable	
Percent of use is on-site renewable	
24 hours of maintenance staff traning annually	
Preventative maintenance program	
Performance monitoring of space conditioning equipment	
Are HCFC or Halon used in the building?	
Refrigerant loss rate per year	
Is lighting electric separately metered?	
Are plug or process electric separately metered?	
Track, record and report emission reduction efforts?	
Document sustainable building cost impacts?	

Authorizations

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ASHRAE 1286-TRP Research Project Hotel Survey

Instructions

The questionnaire is to gather information about your building so it may be assessed using five different benchmarking systems as part of ASHRAE research project 1286-TRP. The five benchmarking systems are LEED-EB, ENERGY STAR for Buildings, ARCH/CAL-ARCH, EnergyPrism, and BREEAM. Using the dropdown lists makes completing this questionnaire simpler. Please complete this questionnaire and send it by email to Jason Glazer at jglazer@gard.com.

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Identification	**Response**
Name	
Building Name	
ZIP Code	
General Building Information	
Building Energy Code	
Year Facility Built	
End-Use Energy Sources	
Primary Heating Source	
Secondary Heating Source	
Primary Cooling Source	
Secondary Cooling Source	
Water Heating Source	
Refrigeration	
Gas Cooking	
Electric Cooking	
Gas Laundry	
Electric Laundry	
Interior Lighting	
Exterior Lighting	
Physical and Operation Building Attributes	
Total Floor Area (sqft)	
Unheated Floor Area (sqft)	
Number of Floors	
Percent Air Conditioned	
Closed or limited operation in summer?	
Closed or limited operation in winter?	
Points from Specific Benchmarks	
Building operation plan developed and followed?	
Are CFC refrigerants used in the building?	
Percent of use is off-site (Green-e) renewable	
Percent of use is on-site renewable	
24 hours of maintenance staff traning annually	
Preventative maintenance program	
Performance monitoring of space conditioning equipment	
Are HCFC or Halon used in the building?	
Refrigerant loss rate per year	
Is lighting electric separately metered?	
Are plug or process electric separately metered?	
Track, record and report emission reduction efforts?	

Document sustainable building cost impacts?

Authorizations

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